DEFENSE RESOURCE MANAGEMENT STUDY

Case Studies of Logistics Support Alternatives

A Companion Report to the Final Report

February 1979

Defense Resource Management Study.

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Donald B. Rice
Study Director

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Donald B. Rice
Study Director

Case Study Contributors

LTC Daniel P. Buono, USA
Morton B. Berman
Manuel Carrillo
Irving K. Cohen
Stephen M. Drezner
LCDR Lloyd B. Embry, SC, USN
LtCol Donald A. Frisbee, USAF
Richard J. Hillestad
Thomas P. Lippiatt
Chris D. Roach
John Shank
Capt Ronald E. Sortor, USAF
Charles L. Trozzo
LTC Frank A. Waskowicz, USA

PREFACE

The Defense Resource Management Study (DRMS) was commissioned by the Secretary of Defense in November 1977 in response to a request by the President dated September 20, 1977. The President wanted a "searching organizational review" into several resource management issues.

The Secretary also established the Defense Organization Committee, chaired by the Deputy Secretary, to oversee the DRMS and several other concurrent organization reviews.

The DRMS focused on five topics within the broad area of resource management:

- Resource allocation decision process (PPBS)
- Weapon system acquisition process
- Logistics support of combat forces
- Career mix of enlisted military personnel
- Military health care system.

Each topic is treated in a separate chapter of the Final Report containing analysis and recommendations for change.

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This companion report presents five case studies of logistics support alternatives. These case studies furnish part of the basis for the design principles for logistics activities described in Chapter III of the Final Report. They also point out specific opportunities to improve defense logistics activities, and illustrate special adaptations that must be made to the general principles in concrete applications.

Several factors impelled the DRMS examination of logistics alternatives:

- Logistics support accounts for a large proportion of defense manpower and dollar resources;
- Past studies of maintenance and supply support have indicated that changes in logistics support concepts and procedures can significantly affect combat effectiveness and cost;
- Peacetime drives for efficiency have sometimes reduced combat flexibility and effectiveness out of proportion to any cost savings; and
- Changes in the expected wartime scenario and weapon system technology have not always induced corresponding changes in the logistics support structure.

These factors supplied the initial motivation for the five case studies that DRMS carried out during its analysis of support to combat forces. The case studies centered on:

- Navy carrier-based air units,
- Air Force B-52/KC135 weapon systems,
- Air Force A-10,
- Army helicopters, and
- Army tracked combat vehicles.

Four design principles emerge from these case studies that should guide the future evolution of logistics support structures.

- (1) Focus the maintenance capability of combat units (Army divisions, Navy and Air Force wings) on quick-turnaround repair, limiting their need to perform off-equipment maintenance. This will free the combat units from a cumbersome logistics burden, making them more able to respond to fluid battle conditions.
- (2) Consolidate off-equipment maintenance at a level that permits capture of economies of scale and reduces the vulnerability of some support resources. The specific design for each weapon system will be dictated by weapon technology, support technology, economics, and the combat task.
- (3) Give theater or fleet commanders the capability to reallocate support resources across combat units so as to adjust quickly to the rapidly changing wartime environments they are likely to face. and (4)
- Reduce, but not eliminate, the dependence of combat units on the CONUS wholesale structure for both maintenance and supply support in order to make the theater somewhat more self-sufficient.

The DRMS examination of logistics support alternatives, described in Chapter III of the Final Report and supplemented by this companion volume of case studies, not only points the direction for future logistics structure evolution, but also illustrates the type of support analysis that should be given more emphasis in the resource allocation and acquisition processes.

* * * * *

Throughout the course of the study, the DRMS has worked closely with the OSD staff, the military departments, the service staffs, field organizations, the OMB, and former DoD officials. The report has benefited immensely from the advice and criticism received from those groups, as well as that received from the Defense Organization Committee. However, the cooperation of others with the DRMS work in no way signifies that they endorse this report. Although the report incorporates numerous observations or comments from others, the Study Director bears the sole responsibility for its content.

Donald B. Rice
Study Director

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SUMMARY

Direct observation, review of data, and interviews indicate general agreement that aircraft availability and capability on carriers suffers seriously from inadequate spares availability. The problem could become more severe in wartime, when several carriers may be engaged in simultaneous operations involving intense flying activity and hence increased demands for stock. Prolonged interruptions of resupply from ashore are to be expected as well. A review of Naval carrier-based air support operations suggests that changes in a small, integrated set of resource management policies governing maintenance, supply, and transportation are likely to improve the wartime effectiveness of Naval aviation. This improvement probably can be achieved at current support costs, and perhaps even at lower ones.

SOURCES OF THE PROBLEM

Several explanations might account for current spares shortages that affect combat aircraft availability and capability. One is lack of funding. Another is the long lead times required for remedial action. Still another is the very small scale of much of the support operation. Although the Navy's flight-deck operations exploit the small scale of its organizations to enhance effectiveness, other aspects of the small scale introduce inefficiencies and resource management complexities that reduce effectiveness and increase costs. Consider the following examples:

- The primary source of the scale problem can be attributed to the many squadrons (9-10) that make up a carrier air wing. Each of these squadrons has few aircraft (4-12).
- The multiplicity of small squadrons is further complicated by the separation of the same aircraft types into different squadrons, which denies shipboard management some of the benefits of pooling aircraft and support resources.
- The peaks and valleys in workloads on a carrier have led to the policy of Temporary Assigned Duty (TAD) personnel being moved from ship to shore to follow the workload. This instability of work location is believed to introduce several inefficiencies.
- In estimating manpower requirements, further inefficiencies are introduced by assigning TAD personnel to squadrons as if each squadron operates in isolation from the others. This policy inhibits cross-utilization and cross-training opportunities, with the net result that workloads faced by TAD personnel are likely to be smaller than if TAD personnel requirements were consolidated.
- The small workloads faced by TAD personnel are further aggravated by the splintering of Naval Enlisted Classifications (NECs) into a large number of specialties. The small workloads and the small populations to meet them are believed to create skill and quality problems.
- The presence of many aircraft types on a carrier, but only a few aircraft of each type, limits opportunities for providing a wide range and depth of spare

parts. This is especially true for bit and piece (B&P) parts required to repair shop-replaceable assemblies (SRAs). Limited stowage space and the size of the management burden also may limit the range of parts stocked aboard ship.

- Queueing difficulties occur at test equipment, which is unreliable and suffers from its own problems in stockage and skill shortages, partly owing to the small scale. Solutions to these problems are difficult and their costs seem large, in view of the small workloads.

The foregoing sources of the scale problem have individually or jointly caused spares shortages, have contributed to increased numbers of aircraft in the status of "Non-Mission Capable due to Supply" (NMCS), have extended Repair Cycle Times (RCT), have increased Beyond the Capability of Maintenance (BCM) actions, have decreased Mean Time Between Failures (MTBF), have caused high Awaiting Parts (AWP) rates, and have resulted in high support-resource costs, especially for manpower.

These problems have made it difficult for the carrier to achieve desired levels of self-sufficiency. As a stop-gap measure, stock is redistributed from one carrier to another to combat spares shortages. However, despite aggressive action by Type Commanders to deal with shortages, it remains unclear how long carriers, in the numbers that some scenarios require, can operate effectively in the face of shortages and resupply interrupts.

Vigorous action needs to be taken to reduce stock shortages that will be a continuing problem for the support system. Besides additional funding and reducing lead times for obtaining and using this funding to provide more spares, the Navy needs to press for a more responsive support resource management system.

POLICY ALTERNATIVES

In light of the foregoing, this study discusses an integrated set of resource management system alternatives. They are intended to increase carrier aircraft availability and capability, and do so over an extended resupply interrupt period at given cost levels. They include the following:

- Consolidation of fighter and light attack squadrons.
- Increasing the scale of repair at AIMDs (Aircraft Intermediate Maintenance Departments) ashore.
- Improved capabilities for redistribution of stock by Type Commanders.
- Establishment of a more responsive transportation system.
- Changes in AIMD manpower requirements and personnel management.

CONSOLIDATION OF FIGHTER AND LIGHT ATTACK SQUADRONS

The consolidation of fighter and light attack squadrons would pool aircraft into 24-UE squadrons, whose availability and capability should exceed that of 12-UE squadrons. For example, consolidated squadrons offer more opportunities to reduce the number of NMCS aircraft. The small groups of hands-on personnel now effectively used on the flight deck will not be touched by this consolidation, but overhead billets can be saved. Consolidation will also reduce the number of TAD billets required and (though not dealt with in this report) probably would also save some non-flight-deck billets. Thus, while effectiveness is increased, billets are freed up at the same time. The savings might be used to help defray costs of additional stockage protection.

INCREASING THE SCALE OF AIMD REPAIR ASHORE

The scale of AIMD repair ashore would be increased by moving to it some of the repair that now takes place on carriers and at depots. To help assure effectiveness benefits that might accrue from this action, it is suggested that these AIMDs be redesigned as production-oriented facilities that support some portion of component repair (especially Avionics components) from carriers, in addition to repair work for shore-based operations. A Level-of-Repair Analysis (LORA) that includes such a shore-based AIMD is likely to substitute AIMD repair for a very large portion of items that are now repaired at the depot. This will dramatically reduce pipeline times for such items. Low-frequency repair that now occurs on the carrier is also likely to be moved to the shore-based AIMD. It is expected that an approximation to the repair of Weapon Replaceable Assemblies (WRAs) now found in the rotatable pool will remain aboard the carrier. Virtually all SRAs and nonrotatable pool WRAs would be repaired at shore-based AIMDs. Limiting shipboard workloads should simplify supply and AIMD management and reduce repair cycle times for remaining workloads. At the shore-based AIMDs, the scaled-up activity should make more bits and pieces and more SRAs available. It will also promote more effective use of test equipment as well as more effective skill development through the increased workloads for those NECs that now see very little action aboard ship. Quality improvements, resulting in improved reliability, are expected for items repaired at the shore-based AIMDs.

The increased pipelines caused by the non-rotatable pool WRAs as well as all SRAs being repaired at AIMDs ashore instead of on the carrier would be compensated by: AIMDs ashore repairing many of the items that are now BCM'd to the depot; reduced repair cycle times ashore and afloat; reduced AWP; increased MTBF; an improved fleet repair priority and distribution system; and reduced manpower costs through consolidation ashore. A limited analysis for the S-3A indicates that—considering improvements in AWP, BCM, and RCT only—the increased repair at the AIMD ashore shows promise of outperforming the current system under conditions of continuing resupply and for some substantial period of time when resupply is cut off. With MTBF improvements, with payoff of an improved fleet distribution and repair priority system as discussed in the next paragraph, and with the likelihood of significant manpower savings (see below), the alternatives in combination should provide more serviceables at the aircraft at much less than current costs.

IMPROVED CAPABILITIES FOR REDISTRIBUTION OF STOCK BY TYPE COMMANDERS

To meet stock shortages, the Type Commander sometimes moves stock from one carrier to another, depending on relative priority. Using the greater scale of stock repaired at shore-based AIMDs, the Type Commander will have more opportunities to distribute this pooled stock routinely to ship-based and shore-based organizations that need it the most or are expected to need it. In dynamic environments with changing priorities and demands for stock, this improved capability could have significant payoffs, especially if the variable demands can be forecasted with reasonable accuracy.

Tied to this improved control of stock distribution would be a capability for establishing repair priorities in light of fleet wide needs. Also, if multiple shore-based AIMDs that repair similar (common) components are retained, such components are shipped to those AIMDs that can minimize repair pipelines in accordance with priorities established by this distribution control system. This control is also to assure that components shipped to depots for repair genuinely require the attention of a depot instead of a shore-based AIMD.

ESTABLISHMENT OF A MORE RESPONSIVE TRANSPORTATION SYSTEM

The current logistics support structure depends heavily on responsive transportation (including COD aircraft). If carriers are to survive long resupply interrupts, it is especially important that transportation be responsive when resupply is possible. Such responsiveness will assure that states of readiness will be so high that the carrier will remain effective longer when interruption does occur. The Navy is conducting a study to upgrade Carrier Onboard Delivery (COD) aircraft. An updated COD capability is urgently needed. Under the alternative of increased repair ashore, it may be that additional transportation capability will be required because more components are moving on and off the ship. Although no specific data concerning weight and cube requirements are available at this time, it is estimated that the number of WRAs and SRAs moving on and off the ship would be approximately double what they are under the current structure.

CHANGES IN AIMD MANPOWER REQUIREMENTS AND PERSONNEL MANAGEMENT

Issues of personnel skill, productivity, and retention rates affect the drive for greater effectiveness. The associated problems arising from the small scale of the workload aboard ship should be eased by shifting low-activity workloads to scaled-up, shore-based AIMDs. The effects of such a shift must be estimated, however.

The Navy's experimental manpower requirements method, called ACM-02, was used for workload estimating and permitted estimation of manpower that would be moved ashore. It also made it possible to estimate the effects of onshore consolidation of small portions of workload from six carriers. The method also revealed the scale payoffs of squadron consolidation. For the limited analysis undertaken, various forms of consolidation promise large savings in manpower. (Independent of consolidation, significant savings also appear likely as a result of the Navy's using ACM-02 to estimate manpower requirements.) The net effects of these policies thereupon raised questions about the wisdom of TAD personnel being managed by squadrons. Under the alternative policies, more of the workload would be brought to people with stable assignments at the shore-based AIMDs rather than bringing so many people to the workload. The smaller populations remaining aboard the carrier would have to be pooled; their skills could not be allocated equally to each of the squadrons under current rules without large increases in carrier manning, which are not justified by the workload. As an alternative, the shore-based AIMD Commander would assume responsibility for AIMD personnel. He would negotiate all AIMD manpower requirements wherever they might be needed. He would also be responsible for the training of I-level specialists. To assure that the carrier is indeed favored in manpower assignments, shore-based AIMD Commanders would report to the Type Commanders, and the shore-based AIMDs would become tenants on the NAS.

Given a dramatic increase in the proportion of AIMD personnel ashore over those who are ship-based, and given the presumption that sea duty is one of the major reasons for the retention loss of many second-termers, the alternative policies can be expected to result in more experienced personnel as well as lower training requirements and costs. A "back of the envelope" analysis is provided to obtain some sense of the impact of improved reenlistment rates. Given the assumptions made in this analysis, the payoff in more experienced (and hence more effective) personnel seem large.

It is finally concluded that the set of interrelated policy and management changes to improve aircraft availability and capability are sufficiently reinforced, by the logic provided and by the outcomes of the limited analysis, to warrant further staff and study pursuit by the Navy. It is also suggested that the ideas in the report could have relevance for other Navy air operations as well as for other Navy platforms.

I. INTRODUCTION

The DRMS review of the resource management system that supports aircraft carrier operations found that the outputs of the system, as measured by aircraft availability and capability, are less than desired. Much of the problem seemed to be due to shortages of spares. One obvious solution, then, is to press for more money, and money probably is the answer for a range of defensible objective functions. However, the current system seems to be afflicted with enormously long lead times in identifying requirements and ultimately meeting them at the aircraft. The Navy has been very successful in reducing several of these lead times, but others remain and persistently cause shortages. Under such circumstances, the Navy should not only press hard on the requirements side, but also step up its continuing reexamination of its resource management system.

Section II of this report discusses current effectiveness levels. Section III examines obstacles to effectiveness gains, most of which seem to be related to an aspect of "scale." Section IV presents an integrated set of policy and organization alternatives, some of whose details are discussed in Section V, "Organizational Level Maintenance," Section VI, "Maintenance and Supply Performance Explorations," and Section VII, "AIMD Manpower, Organization, and Reenlistment." Section VIII presents concluding remarks. Appendix A provides some background information to carrier operations and organization. Appendixes B and C provide manpower details for organizational and intermediate level maintenance, respectively. Appendix D provides details regarding potential reenlistment improvements. Appendix E discusses an exploratory analysis of a subset of the alternative policies on maintenance and supply performance.

II. CURRENT LEVELS OF AIRCRAFT AVAILABILITY AND AIRCRAFT CAPABILITY

In a recent orientation visit to an aircraft carrier, data with regard to aircraft availability, "holes" in aircraft (NORS), and the number of NMCS aircraft were reviewed. The data proved disappointing, especially because resources, including spares, are apparently justified and provided on the basis of the higher activity levels programmed for wartime.

After the first day of operations, for example, 25 percent of the aircraft had NORS conditions and about 25 percent of reparable generations were flagged BCM. For the entire month of June 1978, the average repair turnaround for all work centers on the carrier was almost 10 days (excluding components in AWP status), and the percentage of man-hours utilized was low in most work centers. These apparent problems in supply and maintenance effectiveness may have been largely due to the carrier's mission during this period, but they are still cause for concern.

Within the first few days of operation, considerable queuing occurred at equipment such as Versatile Avionics Shop Test (VAST), partly because of the time required for fault isolation for each failed component, and partly because of equipment unreliability. Furthermore, there seemed to be some concern about bit and piece part availability. This brief visit suggested that, despite the relatively low workloads, problems with supply, skills and test equipment interfered enough with the availability of serviceables to degrade aircraft availability and capability.

In discussions subsequent to this orientation visit, it was suggested that because of the carrier's operational mode it was not outfitted with its "full" Aviation Consolidated Allowance List (AVCAL). This raises questions concerning the number of AVCALs that exist and whether shortages are sufficiently severe to necessitate the shuffling of stock from one ship or shore installation to another.

A review of 3M data over a six-month period for each aircraft type and for all carriers seems to confirm further the need for improvement in aircraft availability and capability. NMCS numbers indicate that aircraft on deployed carriers are faring much better on this dimension than aircraft on nondeployed carriers. This suggests that Navy management is doing well in favoring deployed carriers, but the very need for *this kind* of differential treatment in peacetime is a further indication of shortages in the system. These shortages may worsen with increased wartime activity rates and with the need to deploy more carriers under some wartime scenarios.

For the most part, interviews with a number of officers revealed a similar concern over spares and the repair aspects of the system. Other officers seemed less perturbed, however, on the grounds that only a small number of carriers are likely to be engaged simultaneously in wartime, and available stock should support them adequately. The validity of that belief, of course, depends on the scenario.

During a visit to the Aviation Supply Office (ASO), the opinion was volunteered that poor spares support is basically an issue of "lead times." When new aircraft enter the inventory, initial provisioning of spare parts is very conservative because most inputs to requirements models are little more than engineering estimates and the wrong parts could be bought. The opinion was expressed that this caution is appropriate, even though spares support may be poor in the initial years of operational use. In these initial years, empirical data are gathered for analysis. This turns out to be a protracted process. Special analyses are required to obtain improved estimates for use in requirements models. Subsequent procurement must then go through the approval chain, the POM cycle, the budget, and finally, the procurement lead times. With such elapsed times, so it is argued, "It's just difficult to catch up." Finally, weapon system changes cause this cycle to be never-ending.

This point of view is reported here to suggest that remedial action will require more than additional funds. Because the current system can be characterized as a system of shortages, more responsive and effective resource management systems are needed. The Navy is sensitive to this need. It has several initiatives under way that seem to deal with the realities at hand. The explorations covered in this paper are intended to do the same. As a matter of fact, the observations made during the carrier visit mentioned above motivated this particular concern for improving aircraft availability and capability.

III. SMALL SCALE: A KEY SOURCE OF THE PROBLEM

The resource management system associated with the support of carrier air wings does not have much scale. This small scale sometimes enhances effectiveness (see Sec. V), but more typically impedes it. As one might expect, small scale increases costs per unit; attempting to increase effectiveness without changing scale is likely to involve high costs.

This section discusses various aspects of scale that seem to degrade aircraft availability and capability. Many of the alternative policies and organizations proposed for study are based on this discussion.

A carrier air wing has 9 or 10 squadrons, each with a small number of aircraft — as few as 4 and as many as 12. (See App. A for a more complete picture.) The aircraft in some aircraft types are split into two squadrons. For example, there are 24 A-7E aircraft split into two squadrons of 12 aircraft each.

Prior to 1971, carriers operated as CVAs (primarily fighter and attack aircraft) or as CVSs (antisubmarine aircraft). In 1971, all carriers were configured as CVs, giving them a full spectrum of mission capabilities. This requirement significantly changed the scale of operations to be supported by the resource management system. Policies appropriate before 1971 may be less so now.

The large diversity of aircraft types in small squadrons is further complicated by the peaks and valleys in activity. Work generates aboard a carrier as a function of whether it is in a deployment mode, at home in port, steaming at sea, etc.

Against this backdrop, some of the problems that arise are discussed for the following resources: aircraft, AIMD manpower, test equipment, and stockage and transportation.

AIRCRAFT

The F-4J or F-14A and the A-7E aircraft are divided into two squadrons for each of these aircraft types. These dual squadrons within an aircraft type operate rather independently of one another. Having squadrons made up of 12 UE aircraft rather than 24 gives up some benefits of pooling. The smaller squadron is likely to invite higher overall NCMS rates and decreased aircraft availability. This possibility is discussed in greater detail in Sec. V.

AIMD MANPOWER

The Navy has centralized its intermediate maintenance capability aboard aircraft carriers and at Naval Air Stations. Thus, in contrast to the case of organization-level (O-level) maintenance, the AIMDs have taken advantage of scale for the significant permanent portion of the AIMD concerned with overhead and administrative billets (control, analysis, quality assurance, division offices, etc.). Some of the other functions of the permanent party are concerned with the maintenance of AGE, PME, NDT, and VAST.

However, the work of Temporary Assigned Duty (TAD) personnel from each of the aircraft squadrons who repair components in the AIMDs consists of very small-scale activities that have not benefited from consolidation. Avionics skills, especially, are fragmented into a large number of NECs, with a very small number of personnel within each NEC facing low workloads. These low utilization rates are probably not conducive to skill development. Also, these small populations within an NEC probably do not make it easy to justify high levels of technical supervision. Skills vary across people. Where the populations are large within an NEC, there is a higher likelihood of being able to match the skills available with job requirements. Because this likelihood drops considerably when the populations are small, quality as measured by MTBF is likely to suffer and BCM rates are likely to increase. Despite the fragmentation of skills, and perhaps because of it, interview data suggest that skill problems occur aboard ship, and are worsened by the low reenlistment rate among second-termers. It is difficult to enhance effectiveness under such circumstances.

The policy of moving people to workloads ashore and at sea would seem to have its costs in terms of unstable work environments, which are not conducive to high productivity. It seems a doubtful policy to use squadrons to manage these TAD personnel when such squadrons are not involved in AIMD functions. The logic for doing so is not clear. The squadron should be free to concentrate exclusively on sortie generation.

Given the small scale of carrier air support, one would expect high manpower costs, and the squadron orientation seems to increase those costs even more. I-level TAD personnel work in a consolidated environment, yet they are manned on a squadron basis as if each squadron would have occasion to work in isolation of the consolidated environment. Thus an individual unit's intermediate maintenance personnel requirements are determined without consideration for the effects of consolidation. Each squadron of a given type of aircraft has the same number and skill types of I-level personnel, a practice that fails to take advantage of the scale they can achieve when working together in the AIMD.[1] Apart from these lost scale opportunities, one would expect to find some commmonality of skill in certain areas across aircraft of different types, especially with some modest amounts of cross-training. The effects of such consolidation within AIMDs are also largely ignored in determining a squadron's TAD requirements.

The AIMD manpower area would seem to benefit from improvements in scale to enhance effectiveness as well as reduce costs.

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[1] It is recognized that squadrons typically negotiate manpower requirements with AIMDs on ship and ashore and may provide only that marginal increment of people required for the next interval of time. The residual not required by the AIMD presumably stays with the squadron. The squadron may use such surplus people to perform other needed functions in the squadrons and/or for training. This opportunistic ad hoc use of such skilled people deserves examination, especially since this increment is believed to be large.

TEST EQUIPMENT

The proliferation of aircraft types on a carrier creates serious test equipment problems. Having separate equipment for each aircraft type is costly in a number of dimensions, including space. The problem can be viewed as one of scale. For this reason the Navy has gone to "general purpose" test equipment such as VAST.

That recourse has caused problems of its own. Test equipment, especially that used for testing avionics components, has typically turned out to be less reliable than anticipated. It has spares provisioning problems of its own, and skill problems are associated with its operation and repair. On VAST, for example, set-up times for WRA/SRA test are substantial. Nevertheless, because of the scale of activity at the AIMD, there is not much opportunity for batching. In addition, frequent occurrence of AWP could double requirements for test station time because, after a fault diagnosis has been done, the item has to be removed from the test station to await availability of required parts, thus necessitating another set-up time. One indication of the serious queuing problem being encountered on VAST is cited in the review of minutes of a recent E-2C meeting under the NORS Improvement Program (NIP). Those minutes discussed the lack of adequate access to VAST because of higher F-14A, S-3A priorities. As a result, one of the several recommendations made was to provide another VAST for each carrier.

These test equipment problems extend repair cycle times and increase BCM rates.

STOCKAGE AND TRANSPORTATION

The foregoing discussion of the component repair process indicates that, because of scale problems, actual BCM rates, repair cycle times, and quality of repair (MTBF) are not as good as the more "ideal" values typically used in initial-provisioning stockage requirements models. This kind of discrepancy would obviously cause stock shortages. Those shortages are reflected by the high NMCS percentages. This measure reflects not only the amount of spare parts (stock level) on the ship, but also the ability of the maintenance organization to repair broken components promptly. (It also should be noted from the foregoing discussion that the policy of having separate squadrons of the same type may contribute to the high NMCS rates.)

AWP times also prolong repair cycle times. Empirical AWP times are quite long, for a number of reasons in addition to those discussed above. The small scale of the operation, given current requirement computation methods, yields zero stock level requirements for many low-demand items. This is especially true of bit and piece parts required to repair SRAs. This means that even though they are low-demand items, demands will always occur for some of them, causing an immediate AWP condition. Another factor that may also limit the range of parts stocked is the stowage space aboard ship. Clearly, all items required to fix all components cannot be put on one ship, especially when it supports six or seven aircraft types. This limited range of parts has a "ripple" effect on AWP. For S-3A components, for example, an SRA typically requires two to five bits and pieces in order to accomplish repair. If one of those parts is not on the ship, then the SRA is AWP. In turn, if that SRA is required to repair a WRA, the WRA is also AWP. There are also limitations aboard ship in the management of the many bits and pieces that are stocked. As an indication of the extent of this problem, action is currently under way to provide a special support package merely to help the carrier store and find its very large number of piece parts.

Difficult access to repair parts may also prolong repair times. Parts are typically not stowed in areas or in ways that are convenient to where the repair is being done. As a result, it takes time to obtain a needed part, and test equipment is tied up until it arrives.

Given stock shortages, an especially responsive transportation system is indicated. For a carrier to be able to operate during periods of no resupply from ashore, it becomes especially important to have a responsive transportation system so that high states of serviceable spares readiness can be maintained. The Navy recognizes the limitations of the current transportation system, and has a study under way to update its COD requirements.

Before closing this section, it should be mentioned that systems with particular kinds of stock shortages may call for special kinds of distribution systems. That topic is picked up briefly in the next section.

IV. OVERVIEW OF ALTERNATIVE POLICIES AND ORGANIZATIONS

The following alternative policies and organizations are suggested for review and analysis.

CONSOLIDATION OF FIGHTER AND LIGHT ATTACK SQUADRONS

This reorganization is intended to obtain the benefits of aircraft pooling while at the same time providing the small scale of Autonomous Maintenance Units (AMUs) to operate the flight deck. The pooling is likely to increase both aircraft availability and capability by reducing the number of "downed" aircraft as well as reducing NMCS rates. The consolidation will also save both overhead billets and TAD billets. Although the possibility is not addressed, it may also save billets in non-flight-deck aircraft maintenance. (Section V discusses the effectiveness and manpower issues in O-level maintenance; Sec. VII discusses the effect of squadron consolidation on TAD billets.)

INCREASING THE SCALE OF AIMD REPAIR ASHORE

Under this policy change, the shore-based AIMD is to provide direct support to carriers. The shore-based AIMDs are reorganized to become production-oriented establishments, each of which is set up to serve a particular aircraft type (see Sec. VII). *One effect of this change will be that some items currently* BCM'd *to the depot will* be sent to the shore-based AIMD instead. It has been estimated that a high percentage of reparables—perhaps 50 to 80 percent—are currently declared BCM although technically they may not call for depot repair. Because the shore-based AIMD can operate on a much larger scale than the AIMD aboard a single ship, it is likely to minimize problems such as lack of skills, lack of repair parts, and congested test equipment scheduling, which cause reparables to be declared BCM and moved off the ship in the first place.

If a substantial portion of currently BCM'd reparables were moved to shore-based AIMDs, an immediate gain would be realized because of the difference between the average depot repair cycle time and average AIMD repair cycle time, even if we assume the transport time to be unchanged. The former is on the order of 50 days or more, whereas even in the current structure the latter is around 10 days.

Another suggested change is to move some repair from the ship to the shore-based AIMD. One option under this change is to retain the repair of rotatable pool WRAs on the ship, but to move the repair of the rest of the items off the ship to the shore-based AIMDs. The logic for retaining the repair of rotatable pool WRAs on the ship is that these items are likely to be the more critical items, as well as being the ones with higher demands and higher costs. (A more detailed level-of-repair analysis (LORA) may suggest retaining some variation of the current rotatable pool.) For all

SRAs and for those nonrotatable pool WRAs no longer repaired aboard the ship, additional stock will have to be provided to cover the off-ship pipeline times. For the S-3A, for example, items whose repair is to be moved off the ship under this policy option constitute only 5 to 10 percent of the dollar value of total demands. Thus the cost of extra stock will not be overwhelming. (However, in terms of the number of items, they constitute 40 to 45 percent of the total.)

This action is expected to improve shipboard repair time for rotatable pool WRAs because of factors such as (1) reduced workloads leading to less queuing for test stations, and (2) fewer test-station scheduling problems because of the elimination of SRA-WRA conflicts. As a matter of fact, the S-3A rotatable pool WRAs currently take less than the average RCT of 9.5 days. With the improved scale at the shore-based AIMDs, such improvements as less AWP, improved quality (MTBF), and reduced repair cycle times are expected.

The consolidation of SRA and nonrotatable pool WRA repair is expected to increase the percentage of total repair personnel at shore-based as opposed to ship-based AIMDs. to such information. Type Commanders now redistribute stock rhe consolidation. It is not possible at this time to make a direct connection between the repair moved off the ship and the manpower effect. However, some insight regarding this effect has been gained by estimating the manpower consequences when moving very low workloads off the ship.

Section VI provides an exploratory analysis using S-3A data for assessing the costs and benefits of using AIMDs ashore and afloat in the ways described. The last several paragraphs in this section, as well as Sec. VII, discuss the manpower and organization consequences of the options discussed.

IMPROVED CAPABILITIES FOR REDISTRIBUTION OF STOCK BY THE TYPE COMMANDERS

Given stock shortages, coupled with dynamic demands and changing priorities for stock, effectiveness is likely to increase if the distribution system is sensitive to these needs. Distribution systems that are tied to "oldest requisition" kinds of decision rules are quite appropriate to environments in which there is little change in need overtime. For the more dynamic wartime environment in which shortages exist, it may be necessary to change priorities frequently in light of changing, as well as anticipated changes in, operational conditions. Decision rules tied to changing operational conditions require information that may be available at only a few locations. For purposes of this discussion it is assumed that Type Commanders have routine access to such information. Type Commanders now redistribute stock under special circumstances. Under this proposal the Type Commander's capability is upgraded to permit routine redistribution.

Accordingly, given the shore-based AIMD repair of components for carriers, the Type Commander is now in a position to decide routinely where to redistribute these repaired components. In such a system, too, he is able to set up repair priorities to reflect fleet-wide needs. If common components are repaired at several AIMDs, he also is able to direct such components to the AIMD best able to handle the workload. I peacetime this distribution system is intended to help maintain high states of readiness. It continues to operate in wartime when resupply continues to be possible. If indeed the Type Commander is to operate this redistribution system, rules for allocation of stock among Type Commanders may have to be reexamined.

The management system needed to support this distribution system should not be complex; otherwise, the option is not attractive. Simplicity is advisable for a number of reasons, including the limited information and communications that are likely to be available in some contingencies.

The payoff of such a distribution system needs to be evaluated. Thus, modeling this kind of distribution system is recommended to evaluate alternative decision rules, and to evaluate system performance under an array of operational scenarios to determine those in which the system has higher and lower payoffs. The model should, of course, enable comparison of the current and the alternative system. Since models already exist for such evaluations, it should not be difficult to use or modify one that meets the Navy's needs. This report contains no further information about this proposal to evaluate a dynamic redistribution control system.

ESTABLISHMENT OF A MORE RESPONSIVE TRANSPORTATION SYSTEM

Both the current system and the alternative system require a very responsive COD system. Frequent resupply seems necessary to sustain high states of readiness so that carriers will be able to move into contingencies, be cut off from resupply, and still sustain themselves for, say, a 30-day period at certain activity rates. There seems to be a consensus that an upgraded COD system is required, and there is reason to believe that the Congress has no quarrel, in principle, with an upgrading. If an effective COD system is to be justified, however, the specifics of the requirement need to be defined more clearly. This definition is now under way at the CNA.

Both the current and the alternative systems, then, depend heavily on an effective transportation system if they are to cope with resupply interrupts. It is not clear whether the change in maintenance strategies will require a significantly different system from that required by the current system. It should be noted, however, that under the maintenance alternatives more components are moving on and off the ship. At this time no information is available regarding the weight and cube of the components to be moved. Nevertheless, it is believed that twice as many components would be moved under the alternative system.

Parenthetically, it should be noted that, like all such systems, the current transportation system seems to suffer from long "administrative" delays. Management efforts to reduce delays could help to alleviate shortages.

Although touched upon in Sec. VI, no further substantive information about transportation system requirements is provided in this report.

AIMD MANPOWER AND PERSONNEL MANAGEMENT

The modified policies discussed above obviously have important manpower implications. The result of these alternatives is that a much larger portion of the AIMD population is shore-based than is currently the case. The newly designed shore-based AIMDs are consolidated into scaled-up, production-oriented facilities by aircraft type. (Whether or not there should be an AIMD for some high volume of common items has not been addressed.) These facilities are expected to produce higher-quality outputs. They are also expected to raise second-term reenlistment rates because fewer personnel will be required aboard ship.

Much of this report's quantitative manpower assessment was accomplished with a newly developed model called ACM-02, developed by the Navy Manpower and Material Analysis Center, Atlantic (NAVMMACLANT). Aspects of the model are described in App. C. The model uses historical man-hour data from the 3-M system to estimate workloads. It turns out that man-hours in areas such as the Avionics NECs are small — so small as to suggest that manpower needed for meeting the requirement is of the "firehouse" type rather than manning against specific workloads. These small workloads are consistent with the general theme of this paper. With the many different aircraft types and the skill-splintering that has occurred, the small scale in the man-hour data is not surprising.

Section VI, backed up by detailed information in Apps. B and C, presents some selected analyses of the manpower effects of the foregoing policies. For example, the savings resulting from squadron consolidation are estimated for several kinds of functions. Section VI also discusses the effect of moving very low man-hour skills off the ship and consolidating them at shore-based AIMDs. Some of the numbers disclosed are dramatic, but they should be interpreted cautiously. For example, the low-man-hour skills hypothesized for consolidation ashore may not bear a one-to-one relationship with the skills required to repair the components hypothesized for repair ashore. Furthermore, there are comments about the detailed procedures and rules used by ACM-02 that require resolution before the workloads and manpower savings can be accepted without question. Nevertheless, the direction of data presented appears to be very consistent with the central issue of scale raised by this report.

Section VI also discusses a proposed organizational change of TAD personnel to improve their management. Finally, some analysis is presented concerning the expectation that reenlistment rates will be improved.

V. ABOARD-SHIP ORGANIZATIONAL LEVEL MAINTENANCE

Aircraft in the Navy are assigned to squadrons that may possess as few as four aircraft. These squadrons own the aircraft, provide the pilots and other crew members, and perform organizational level (O-level) maintenance. Although carrier and Naval Air Station operations involve multiple squadrons of the same or different types of aircraft operating together, each squadron is manned and equipped to operate independently. Aboard ship the scale of each squadron is very small. This small scale appears to enhance effectiveness for some purposes and to inhibit it for others. Each aspect will be discussed in turn.

Some squadron personnel operate on the flight deck. During operations, plane captains, troubleshooters, and ordnance load crews are on the flight deck to move aircraft, arm them, and respond quickly to aircraft malfunctions. A cadre of ship's company personnel support the individual squadron's organizational people in their operations. These flight deck personnel operate the catapults and recovery devices, move munitions, operate some of the ground support equipment, and coordinate and oversee flight deck operations.

Flight deck activities seem to attest to the productivity of small, "self-sufficient" squadrons. Specialists are used on the flight deck as troubleshooters to help assure availability of aircraft. They assist plane captains as needed. Team activity reaches high levels. Safety techniques are widely practiced and the control of flight deck operations by senior officers is impressive. The high degree of coordination results in fairly high sortie rates, and a carrier's peacetime operations represent some important segment of the wartime operation.[2]

Because the current organizational structure, despite its small scale, appears to be paying off in sortie production, it would be not be wise to make any important changes in it. However, some aspects of these small squadrons, as discussed in the next several paragraphs, appear sometimes to detract from effectiveness.

Although a carrier air wing will have two squadrons of certain types of aircraft (F-4J or F-14A and A-7E), each squadron performs its mission apart from, and in some ways in competition with, its sister squadron. As a result, each squadron will have its own NMCS aircraft, and frequently no attempt is made to minimize the total number of NMCS aircraft across the multiple squadrons of a single type. Thus, one squadron may have, but may not routinely make available, a component that may fix a hole in a sister squadron's aircraft. The total effectiveness of the two squadrons in terms of ready aircraft is therefore reduced.

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[2] It is interesting to note that the Air Force's tactical forces are transitioning to a flight-line organization called POMO that begins to approximate the Navy flight deck system. In the transition to POMO, many problems are being encountered. Though the carrier's environment is different, it is nevertheless quite likely that the Air Force could benefit from a detailed understanding of the Navy's system.

Mission scheduling is also somewhat complicated by the separate squadrons, as the scheduler must allocate the required sorties between the two squadrons. The fighter and light attack sorties must be balanced between the two squadrons while attempting to compensate for the different aircraft availabilities of each squadron.

Although most commanders are likely to overcome the problems created by maintaining separate squadrons in wartime, it seems unwise to practice and reinforce separateness in peacetime, especially in view of the need to enhance effectiveness.

Manpower diseconomies also arise because each squadron has a full organizational structure. Figure B-1 in App. B shows the structure of organizational maintenance, and Table B-1 shows the squadron manpower requirements as reflected by the aircraft's Squadron Manpower Documents (SQMDs). The effect of the decentralized environment can be seen in the number of personnel required in the overhead work centers (OXX). The 187 people shown in Table B-1 contrast with the approximately 30 people required for the same work centers in the consolidated AIMD aboard a carrier.

The form of consolidation indicated is to combine the two 12-aircraft squadrons into one 24-aircraft squadron for each of the fighter and light attack communities. Such an organization would place all aircraft of a type under a central control, and would require fewer personnel in many areas. Given consolidation, the directed manning positions and the fixed portion of the standard equations of Table B-2 should result in manpower savings. As indicated above, this effect is now realized in the centralized AIMDs as well as in the large (30 or more UE) Replacement Air Groups (RAGs), or training organizations.

Although the current squadron organization seems to enhance effectiveness in flight deck operations, the lack of aircraft pooling across squadrons of the same type seems to detract from aircraft availability and capability. Furthermore, opportunities for saving overhead billets are currently lost.

It seems possible to consolidate squadrons so that the small groups of hands-on people on the flight deck remain untouched while aircraft pooling benefits and scale economies for overhead billets are attained.

The DRMS recognizes that various forms of squadron consolidation have been proposed by outside agencies and by the Navy itself. The status quo also has its defenders. For example, a key argument in favor of maintaining two separate squadrons in the F-4J, F-14A, and A-7E cases is that doing so keeps units at a "manageable" size. That argument carries weight in view of the impressive flight deck operations that seem to result in part from small scale. However, under the two-AMUs-within-a-squadron concept, the small scale can prevail despite squadron consolidation. And the healthy competition that should arise between the two AMUs would generate the same sort of esprit de corps now attributed to the separate squadrons. It is true that some number of command billets will be lost under the squadron consolidation being suggested, and the Navy may consider this a serious limitation; but the Navy should also consider the counterbalancing gains in aircraft availability and capability, and in overhead reductions.

It is fairly easy to estimate the gains in NMCS reductions due to aircraft pooling, given a number of simplifying assumptions; estimating the payoff in improved mission scheduling due to aircraft pooling is likely to be difficult. In any event, this study has not attempted quantitative measurement of the gains in effectiveness due to squadron consolidation, but has estimated potential manpower savings by using the requirements standards for organizational maintenance functions. These equations for the overhead work centers are shown in Table B-2 along with the manpower requirements for an F-14A and an A-7E squadron.

These overhead work centers are not the only work centers affected by consolidation. Two other work centers, indicated by the AMU structure, should also realize savings from consolidation: 130, Aviators Equipment; and 230, Armament. Table B-3 summarizes the manpower savings for these work centers. Adding a 14 percent factor for support personnel, (based on the percentage of "integrated services" personnel in Table B-1), the total manpower savings would be 65 billets per carrier air wing.

Another area that would benefit from the consolidated workload is the intermediate level (I-level) TAD billets in a squadron (the AIMD values in Table B-1). This area is discussed in Sec. VII. Further manpower savings may also accrue in other work centers not directly associated with the flight deck; however, that possibility is not pursued in this report.

Before closing out this discussion of O-level maintenance, a comment should be made about scheduled maintenance that is performed at the O-level. Initial thinking about this topic suggested that aircraft availability could be increased and costs reduced if scheduled inspections were reduced, performed while ashore, and deferred during a contingency. Since that time, more has been learned about the Navy's "reliability centered maintenance program," which is likely to reduce inspections. Also, information has become available suggesting that policies do exist that permit deferral during wartime. As a result, this topic will not be addressed further. We will merely mention in passing that a fairly extensive literature has become available recently about the negative contributions of inspections and techniques for reducing them. If these studies have not come to the attention of the Navy, a review of them may be useful. Also, since the U.S. Air Force's F-4 has had a fairly productive program for dealing with scheduled maintenance, the Navy may wish to visit the Ogden Air Logistics Center to determine whether their past and ongoing programs are relevant to the Navy. The Navy may also find it useful to do a comparative analysis of its F-4 scheduled maintenance program with that of the Air Force.

VI. MAINTENANCE AND SUPPLY PERFORMANCE EXPLORATIONS: AN S-3A EXAMPLE

This section extracts from App. E the results of some initial analysis of the performance implications deriving from the problems faced by the current maintenance and supply structure. In addition, the exploratory analysis provides performance comparisons between the current structure and the structural alternatives previously suggested. Two alternatives were analyzed: that of moving some component repair (SRAs and nonrotatable pool WRAs) from the ship to a shore-based AIMD, and that of diverting some portion of BCM components to that AIMD.

These analyses should be regarded as preliminary, not exhaustive. The intent is to provide sufficient analysis and a relevant methodological approach to warrant further investigation into these alternatives. Given this purpose, only data for the S-3A were explored.

It should be emphasized that this extract provides only a small slice of App. E's detailed information about these performance explorations, which the reader is urged to review.

The supply portion of the S-3A exploratory analysis was performed with a dynamic queuing model of shipboard and shore-based repair. That is, mathematical expressions were derived describing the average number of components in the various parts of the supply pipeline—ship repair, depot repair, transportation, etc. — *as a function of time.* With this description of the pipeline quantities, it was then possible to compute measures of performance, such as the number of components backordered, and an approximation to the number of aircraft NMCS. Of key importance was the fact that measures were computed and shown as a function of time. Traditional analysis of supply performance has usually concentrated on more limited queuing results called the "steady state" performance. Steady-state measures are usually simpler, computationally more tractable, and probably sufficient for investigating peacetime performance. In this analysis, the focal interest is in the potential performance of the alternative structures under *wartime* conditions; consequently, the additional effort has been made to model and compute the measures under wartime dynamics, such as the transition to wartime flying rates and pipeline interruptions.

Several runs were made with this model in order to provide performance estimates of the current structure under a number of conditions. Most of these runs suggest that, under projected wartime activity rates, the dependence on *shipboard repair of SRAs* for WRA repair and on *bits and pieces for SRA repair* diminishes the self-sufficiency of the S-3A squadron.

Other model runs simulated the cutoff of depot resupply at the beginning of a war. Here it was observed that when either AWP due to SRA limitations only or AWP that also includes bit-and-piece (B&P) effects are considered, the NMCS rate rises rapidly after the start of wartime activity. In the latter case, for example, a 30 percent NMCS rate is reached by the 30th day of wartime activity and a *50 percent* NMCS rate is reached by the 60th day. In this cutoff case, where self-protection is most important, it is clear that because of the small scale of operation both the range and depth of B&P stock and SRA stock inhibit the self-sufficiency of carrier operation that is supposedly obtained with shipboard intermediate level repair. Within a few days after cutoff, shortages in B&P stock appear and affect the repair time of SRAs. This in turn causes shortages of SRA components as they sit in the repair pipeline in AWP condition. These shortages affect the repair time of the WRAs, draw down the WRA spares, and holes in aircraft ultimately appear, leading to loss of capability and NMCS conditions.

The results obtained for the current system were then compared with the results for an "equal stockage cost" alternative system in which only rotatable pool WRAs continued to be repaired aboard ship, and other WRAs and all SRAs were repaired ashore. Furthermore, BCM work to the depot was reduced by 50 percent. That reduced work at the depot was undertaken by the shore-based AIMD. Under these alternatives, the benefits assumed were limited to the reduction in AWP, BCM rates, and repair-cycle time at the AIMDs ashore and afloat. The exploratory analysis found that the alternatives show promise of outperforming the current structure under conditions of continuing resupply and for an important period of time when resupply is cut off.

The details of all of these runs appear in App. E. It should be emphasized that the more complete range of benefits that are expected from the alternative system has not been included in this exploratory S-3A analysis. For example, the manpower savings that are likely to result from these particular alternatives (see Sec. VII) have not been included in the exploratory analysis. Such inclusion would, of course, provide further support for the alternatives.

VII. AIMD MANPOWER, ORGANIZATION, AND REENLISTMENT

Much of the information discussed in this section is drawn from App. C. The principal information deals with a manpower requirements analysis related to some of the alternatives. There is also a discussion of AIMD personnel management as well as an analysis of the potential impact on personnel retention.

One of the alternatives discussed above was the consolidation of squadrons having aircraft of the same type. Such a consolidation affects TAD requirements because personnel requirements are currently established for each squadron in isolation.

The Navy's ACM-02 technique for estimating manpower requirements was used in helping to make this assessment. The technique has the advantage of being reproducible. It is not in operational use, however. The Navy's current method for estimating manpower requirements as reflected in SQMDs appears to be largely subjective.

As can be seen from Table C-19 in App. C, the total TAD billets required for the non-avionics work centers on a single carrier, according to ACM-02, are 18 and 14, respectively, for two 12-UE F-14A squadrons and two 12-UE A7-E squadrons. The grand total here is 32, but when consolidated into 24-UE squadrons the total is 20—a savings of 12 billets that can be attributed to consolidation. It turns out that the Navy's total Squadron Manpower Document (SQMD) requirement for these four squadrons is 50, so the potential requirements savings due to the use of the ACM-02 *and* consolidation is 30 billets. (The Navy is not manned to its statement of requirements.)

Table C-20 provides similar data for the avionics work centers. In this case, the ACM-02 requirement for the four squadrons is 86; after consolidation it is 50—a saving of 36 billets. The Navy's SQMD requirements statement for these four squadrons being 134, ACM-02 *plus* consolidation saves 84 billets per carrier.

The foregoing suggests that consolidation of squadrons could save a total of 48 billets per carrier (12 non-avionics billets and 36 avionics billets). For the 12 carriers the total would be 576.

The more interesting case involves the removal of certain repairs from the ship-based to the shore-based AIMD. It was intended that this pilot exercise approximate the manpower effects under the option of the removal of all SRA work and all work for WRAs that are not in the rotatable pool. It is assumed that nonrotatable pool items have low demands and would coincide roughly with low-activity NECs. Thus, it was decided to remove all billets that had less than ten man-hours of work per week (as calculated by ACM-02).

Before putting bottom lines together, it is instructive to review the weekly workloads for the Communication/Navigation shop NECs under each aircraft, as shown in Table 1, which is an extract from Table C-5.

The weekly workload column represents man-hours expended as captured by the 3-M system and assembled by ACM-02. Aboardship personnel are expected to be

Table 1—Communications/navigation shop workloads by aircraft type and NEC

Acft	NEC	Weekly workload (man-hours)	Acft	NEC	Weekly workload (man-hours)
F-14	ET 1447	.9	A-6E/ KA-6D	ET 1447	.6
	AT 6604	1.0		AT 6604	46.0
	AT 6605	1.5		AT 6605	16.8
	AT 6607	.1		AT 6606	16.2
	AT 6609	15.1		AT 6607	1.7
	AT 6611	9.4		AT 6608	2.4
	AT 6612	5.8		AT 6609	.2
	Other	3.8		AT 6611	4.7
A-7E	ET 1447	.8		AT 6612	0
	AT 6604	0		Other	7.6
	AT 6605	15.7	EA-6B	ET 1447	.4
	AT 6607	2.1	(EX-CAP)	AT 6604	21.9
	AT 6608	.1		AT 6605	4.2
	AT 6609	10.7		AT 6606	6.8
	AT 6611	21.9		AT 6607	.4
	AT 6612	18.6		AT 6609	.1
	AT 6617	20.9		AT 6611	2.8
	Other	8.5		AT 6612	0
				Other	3.4
E-2C	ET 1447	.1	S-3A	ET 1447	.3
	AT 6604	.1		AT 6604	0
	AT 6605	0		AT 6605	.3
	AT 6606	2.7		AT 6607	.4
	AT 6607	0		AT 6608	0
	AT 6609	2.5		AT 6609	4.5
	AT 6611	9.6		AT 6611	.3
	AT 6612	2.8		AT 6612	.9
	AT 6633	0		Other	1.7
	Other	5.0			

Note: This is an extract only. See App. C for the complete table, Table C.5.b.

available for work 60 hours a week. The man-hours shown in this extract can be justifiably labeled as "firehouse" manning. For those who suggest underreporting by the 3-M system, it would have to be underreporting by very a large factor indeed to make a difference in the numbers of personnel that would be required for each NEC. For those who have been puzzled that the ACM-02 method is insensitive to flying activity, again this table provides the explanation. It is simply difficult to increase activity rates by the amounts necessary to significantly change personnel requirements decisions. Also, our assumption that a ten-hour-a-week rule would result in roughly the same manpower decisions as the "rotatable" pool option is probably somewhat off the mark. It would seem, from the many tables similar to this one in App. C, that there is simply not much activity generated within each of the NECs. Thus, rotatable pool repair is also likely to suffer from low man-hours worked. The small scale is even less than anticipated.

Before going on, another extract from Table C-5 is provided below as Table 2. In this case the NEC workloads have been summed across aircraft types. These numbers too do not seem very large. However, one wonders whether the Navy has considered cross-training across aircraft and across NECs. It is likely that some such cross-training does, in fact, exist for some personnel. Current manpower requirements estimations apparently do not take such realities into account.

In any event, these data suggest that some very high costs are being paid for shipboard repair. Becoming more efficient about estimating manpower requirements *within* the current structure may aggravate some of the issues of scale discussed at the outset of the report. As suggested earlier, alternative support structures need to be examined to overcome these scale effects. Perhaps it would be more economical and more effective to consider options in addition to the rotatable pool option for repair ashore in the further analysis of this area.

Table 3 summarizes, by work center, the number of billets that will remain on ship and the number that will be removed. This summary was obtained from the details in Tables C-12 through C-18, which show the consequences when the ten-hour rule is applied to each NEC for each aircraft type in each work center. In addition to showing which NECs would move off the ship, a comparison is made between the Navy's statements of requirement in SQMDs and the requirement derived from the workload as computed by ACM-02. This workload is divided by the appropriate availability

Table 2—Comm/nav workloads by NEC aggregated across aircraft types

NEC	Weekly workload (man hours)	NEC description
ET 1447	3.5	Communication Security Devices Equip. (KY-28) Tech
AT 6604	69.0	Integrated COMM/NAV/IFF IMA Tech
AT 6605	40.9	Aircraft Navigation Equipment IMA Tech
AT 6606	30.9	Aircraft Doppler Radar Navigation IMA Tech
AT 6607	4.7	Digital Data Link Communication IMA Tech
AT 6608	11.4	Aircraft Navigation Computers IMA Tech
AT 6609	38.9	Aircraft Electronic Identification (IFF) IMA Tech
AT 6611	59.0	Aircraft Communication Equipment IMA Tech
AT 6612	33.6	Aircraft TACAN Maintenance IMA Tech
AT 6617	20.9	APN-190 Doppler Radar Nav. & APM-341(V) PGSE Tech
AT 6633	0	Communication Security Devices Equip. (KG-23) Tech

Table 3—Manpower implications of moving selected avionics workloads to shore-based AIMD's

	Billets remaining aboard each ship		Billets moved to shore-based AIMD's from 6 carriers[1] (consolidated)	
Work center	SQMD requirements	ACM-02 workload derived[2]	SQMD requirements	ACM-02 workload derived[3]
Com/Nav	14	9	228	31
Elec/Instru	11	5	48	8
Fire control	18	6	------	----
Radar/ECM	12	8	138	16
SACE/inertial Nav	29	13	114	18
VAST	31	9	------	----
ASW	2	1	12	2
Total	117	51	540	75

[1] *Criterion: ACM-02 workloads of less than 10 man-hours/week/workcenter.*

[2] Workload man-hours/week; 60 man-hours available/week.

[3] Workload man-hours/week; 31.9 man-hours available/week.

(Shore = 31.9 hours/week; Sea = 60 hours/week). When a workload is moved ashore it is assumed that it will be consolidated with similar workloads from six carriers.

From Table 3, a 2:1 difference can be seen in requirements for billets remaining aboard ship as measured by SQMD requirements in contrast to the ACM-02 requirement. Of the 66 billets saved, about 20 per carrier result from consolidation of billets from the squadrons with same aircraft types. It is not unlikely that upon closer examination the carrier would have to have some additional billets to support shift and "position manning" in some NECs. (Position manning is merely the number of personnel required to operate, for example, test equipment independent of low workloads.) Another 465 billets are saved by consolidating the work of six carriers in shore-based AIMDs. The total effect in this latter kind of consolidation is extremely large—over 7:1. The following aggregation might be useful:

SQMD statement of avionics TAD requirements for 6 carriers	1,242
Personnel remaining on 6 carriers after consolidation	306
Personnel moved to shore AIMDs for consolidated workload	75
Manpower savings for 6 carriers	*861*

These numbers do not take into account the effect on permanent party personnel at the shipboard AIMD. The consolidation is limited to avionics work coming from the six carriers. It obviously does not take into account the workload situation at the shore-based AIMDs. Obviously, too, the workloads consolidated do not take into account the work that would not go to depot because a sizeable number of the components now BCM'd to the depot would be repaired at the shore-based AIMDs.

One might wish to know what the *authorized* number of Avionics personnel is in contrast to the SQMD requirements statement of 1242 shown above. From Table C-2 it can be seen that the Navy requirement for Avionics is about 70 percent of the total TAD requirement. During a visit to a CV, it was noted that about 230 TAD personnel were authorized; 70 percent of 230 would suggest that about 161 Avionics personnel were authorized. If so, then the 1242 requirements number would be more like 966 (161 x 6). Thus, the manpower savings for the six carriers using the very approximate authorized number would be on the order of 585.

From the point of view of adding more workload and personnel scale to the shore-based AMIDs, the total of 75 billets across all work centers and across all aircraft types seems trivial. Additional means for increasing the scale of these shore-based AIMDs need to be explored. Depots perform considerable I-level work associated with aircraft rework activities. That I-level work is subject to relocation to AIMDs. It may also be cost-effective to consolidate several of the shore-based AIMDs. These possibilities have not been addressed at all.

Also, as suggested above, it is likely that some of the rotatable pool repair of WRAs have NEC requirements of less than ten man-hours per week. It will not be possible to move such billets to the shore-based AIMD. Thus, under the rotable-pool, repair-on-carrier option, low-activity NECs will continue to remain aboard the carrier. That suggests that the cross-training issue does indeed need to be addressed. This low-activity NEC problem may exist in some areas at the shore-based AIMDs. In those cases, in addition to cross-training, it may be worthwhile to investigate whether it makes sense to organize some of the shore-based AIMDs as specialized repair facilities, to enable specialization in the repair of particular components across weapon systems.

The wisdom of having TAD personnel within squadrons is questionable. An attractive alternative would be to transfer responsibility for TAD personnel management from the operational squadrons to the shore-based AIMD Commander. Within a given Type Command, all I-level personnel for a given type of aircraft would represent a pool of specialists available for deployment. These personnel could be ranked according to training status, proficiency, time since last deployment, and preference for sea duty, to indicate a sequence of assignment for the next deployment. Negotiations between the carrier AIMD Commander, who represents the demand, and the aircraft's home-base AIMD Commander, who represents the supply, would decide which personnel would be assigned to the carrier for the deployment. To assure that the shore-based Commander will act in the best interests of the carriers, he should report to the Type Commander and his shore-based AIMD should be tenanted on the NAS.

Such a system would ensure that the assignment would be equitable to all parties concerned: the CV AIMD, the NAS AIMD, and the I-level personnel. The potential benefits may be far-reaching. Currently, TAD levels are fixed by squadron, a practice that may result in excess repair capacity. Nevertheless, the current TAD system does not provide the flexibility to match resources to requirements. The central control of available resources could provide that flexibility, with the mechanism available to assign the proper number of personnel to satisfy an anticipated demand, plus the capability of augmenting those personnel if the need arose.

A possibly higher payoff of having AIMDs ashore in control of all I-level repair personnel is the capability of assigning the properly trained people. Currently, squadrons are assigned TAD people to fill certain billets. The assigned personnel may or may not have the proper skills when they report. It is the squadrons' responsibility, in conjunction with an AIMD or Fleet Replacement Aviation Maintenance Program (FRAMP), to provide the training channels. A common complaint of I-level management is the lack of proficiency of many squadron TAD personnel. A central TAD personnel manager could ensure that personnel assigned to CVs were properly skilled, and could retain at a shore AIMD those men that require training.

A third benefit arises from the possibility of requiring less sea duty of a number of personnel. Currently, TAD people stay with a squadron, and when the squadron deploys, the I-level repairman also deploys. With a dramatic increase in the proportion of shore-based AIMD personnel required over those who are ship-based, the number of sea tours required will be reduced dramatically. Sea duty may be one of the major reasons for the retention loss of personnel. With sea tours reduced, personnel who desire to deploy may be allowed to do so more frequently; the remaining personnel would be required for deployment less frequently. This practice could increase retention, provide more experienced personnel, and lower training requirements and costs.

A "back-of-the-envelope" analysis was accomplished to assess the impact of improved reenlistment rates. That analysis is reported in App. D. It presumes that sea duty is partly responsible for low second-term reenlistment rates for technical I-level shipboard ratings. Therefore, those rates are expected to improve if the majority of the technical ratings are moved from shipborne AIMDs to consolidated shore-based AIMDs. This would especially be true if such consolidation permitted manning ship AIMDs exclusively with volunteers, or if the remaining ship AIMDs were so small a proportion of the total force that sea duty would become an infrequent event.

Appendix D provides some rough estimates of the payoff from improved retention. To make the estimates, the second-term reenlistment rate for the Training Device (TD) rating was substituted for the second-term rate for the Aviation Electrician (AE), Fire Control (AQ), and Electronics (AT) ratings. The TD rating represents both a highly technical rating and one that is almost exclusively shore-based. Second-term reenlistment rates similar to that for the Training Devices rating are also seen for I-level electronic specialties in the Air Force.

The following four tables summarize App. D. Table 4 provides current reenlistment statistics. Table 5 summarizes the expected reduction in recruitment and training of first-term ratings. Table 6 summarizes the expected reduction in training for advanced courses. Table 7 indicates the expected increase in skilled technicians (those with more than eight years service) that results from improved second-term reenlistment rates.

Overall, the net benefits are:

- 13 percent annual reduction in recruits required and their training;
- 15 percent annual reduction in advanced AIMD training billets;
- 40 percent increase in the proportion of the force with more than 8 years service (a measure of increased effectiveness).

In concluding this section, a word might be said about the potential loss in flexibility by moving more and more to a system that is increasingly dependent on stock for avionics systems. Despite the very persuasive array of data that has been assembled that suggests the need to reassess current management and management practices, some officers may rightly wonder about the "flexibility of manpower" losses that might occur with the exchange of stock for manpower. It might be useful to note

Table 4—Navy reenlistment rates by selected ratings through August FY 1978

Rating	Authorized personnel	Reenlistment rate: First-term	Reenlistment rate: Second-term
AE	8,800	.25[1]	.45
AQ	3,327	.38	.24
AT	11,656	.64	.37
TD	2,102	.83	.62

Sources: MAPMIS Report 1133-4229, PERS-212 CREO Management Report, and CNO enlisted requirements plan.

[1] Contains 6-year obligated tour lengths. Actual first-term rate is lower.

Table 5—Reduction in recruiting and technical training loads for selected ratings

Rating	Current	With higher reenlistments	Reduction	Percent reduction
AE	1,386	1,283	103	7
AQ	503	399	104	21
AT	1,240	1,030	210	17
Total	3,129	2,712	417	13

Table 6—Reduction in advanced training loads for selected ratings

Rating	Current	With higher reenlistments	Reduction	Percent reduction
AE	347	321	26	7
AQ	191	152	39	20
AT	793	659	134	17
Total	1,331	1,132	199	15

Table 7—Proportion of selected ratings with more than 8 years service

Rating	Current	With higher reenlistments	Percent improvement
AE	.21	.27	33
AQ	.17	.34	100
AT	.30	.42	40
Total	.25	.35	40

that the nature of avionics systems in advanced weapon systems has reduced the flexibility of manpower. The specialist has much less latitude to base a diagnosis and repair on his own initiative, experience, and intelligence. Technological advances have turned avionics systems into digital, interactive, and integrated systems. They have become very dependent on highly automated test equipment (ATE) for in-flight diagnosis, AIMD repair, and depot repair. No longer does a pilot describe a malfunctioning piece of equipment to maintenance personnel, who proceed to troubleshoot the equipment. Instead, a built-in test equipment light signals a malfunction to the maintenance crew, who remove the indicated item of equipment and arrange for it to be moved to the AIMD. There the equipment is subjected to a complete standard test on ATE. If it fails the test, the indicated plug-in modules are replaced and the test is repeated. If the equipment cannot be repaired, it is sent to the depot, where ATE is used in a similar fashion by more experienced people.

This growth of ATE at all echelons of repair standardizes testing, but it almost completely cuts off communication between the levels of maintenance, and it places total reliance on the fault-isolation capability of the ATE. The flexibility of manpower is reduced while the skill levels required to maintain and use the test equipment have increased. Under such circumstances the carrier's captain should value the availability of stock all the more, for it contributes directly to aircraft availability and capability.

VIII. CONCLUDING REMARKS

This DRMS case study affects a large number of support areas. In the analysis of performance in the supply area, given the described changes in location of some repair and the assumptions about expected maintenance improvements, very important reinforcement to the alternatives seems to have been provided. In the manpower area. too, sufficient data have been assembled to reinforce the alternatives. Other aspects of the support system have been logically discussed, still others have been merely touched upon, and probably some have not been mentioned at all. For example, the case study is silent about the potential need for military construction funds for the suggested increased scale of AIMDs ashore. The case study has also been largely silent regarding the impact of the alternatives on the depot system. Nevertheless, the information assembled does seem to warrant continued aggressive staff and study pursuit by the Navy.

It should be emphasized that most of this report's information and comments have been principally concerned with aircraft avionics systems of carrier AIMDs, with some limited attention to the current state of shore-based AIMDs. The report could have relevance for all other Naval air operations, however. Some of the ideas could also have implications for other platforms within the Navy.

Appendix A
BACKGROUND TO CARRIER AIR WING OPERATIONS AND ORGANIZATION

The Navy currently operates 13 aircraft carriers, 7 on the East Coast and 6 on the West Coast. Each carrier has assigned a carrier air wing composed of squadrons of different types of aircraft. The squadrons deploy with the ship and are stationed at Naval Air Stations when the ship is in port for refurbishment or overhaul. A single Naval Air Station on each coast acts as the home base for aircraft of a particular type. For example, Oceana on the East Coast and Miramar on the West Coast are the bases assigned to fighters (F-4J, F-14A).

A carrier will have 9 or 10 squadrons of up to 8 different types of aircraft, with a total planned load of approximately 90 aircraft. The typical mix of aircraft on board a carrier is shown in Table A-1. Prior to 1971, carriers operated as CVAs (primarily fighter and attack aircraft) or as CVSs (antisubmarine aircraft). In 1971, the decision was made to configure all carriers as CVs, giving them a full spectrum of mission capabilities. However, space constraints caused problems with accommodating all the various aircraft, and carriers currently operate with less than their full complement of assigned aircraft. On the East Coast, a squadron will leave behind a few of its aircraft. For example, fighter squadrons will deploy with only 10 of their 12 UE. On the West Coast, one squadron of fighter or light attack (A-7E) aircraft will be offloaded and operate from a nearby shore installation. Therefore, although a carrier theoretically has 90 or more aircraft, only about 75 will be on board at a given time.

When operating, a carrier spends about half the time in port and half at sea conducting air operations. Table A-2 shows a three-month operational schedule for the *Saratoga* (CV-60). Flight operations typically last 12 hours, but sometimes continue

Table A-1—Typical aircraft mix in a carrier air wing

Aircraft type	Number of squadrons	Aircraft per squadron	Total aircraft
F-4J or F-14A	2	12	24
A-7E	2	12	24
A-6E/KA-6D	1	10/4	14
EA-6B	1	4	4
E-2C	1	4	4
S-3H	1	10	10
SH-3H	1	8	8
Total	9		88

Note: Carriers are also assigned a photo/recce squadron. These aircraft are currently RA-5Cs but are scheduled to be replaced by F-14s carrying photo/recce pods. During peacetime, these squadrons are rarely deployed on board ship.

Table A-2.—USS SARATOGA operations

November, 1977:	14 days at sea
01-02	At sea
03-15	Palma de Mallorca, Spain
16-27	At sea
28-30	Malaga, Spain
December, 1977:	15 days at sea
01-04	Malaga, Spain
05-08	At sea
09-11	Rota, Spain
12-22	At sea
23-31	Mayport, Florida
June, 1978:	12 days at sea
01-06	Mayport, Florida
07-09	Sea trial
10-21	Mayport, Florida
22-30	At sea REFTRA

for 24 or 36 hours. Operations are conducted in hour-and-a-half cycles with (approximately) a half-hour for launch, a half-hour for recovery, and a half-hour for respotting the flight deck and refueling and refurbishing the aircraft. A launch cycle involves 20 to 25 sorties of various missions. Typical launches include 4 to 6 fighter sorties, 4 to 6 light and 4 to 6 heavy attack sorties, 1 tanker, 1 E-2, 1 or 2 EA-6, 2 helicopter, and 3 to 5 S-3A sorties.[1] Although all 4 catapults can be used almost simultaneously under ideal conditions, only one aircraft can be recovered at a time.

The operational squadrons own the aircraft, provide the pilots and other crew members, and perform organizational level maintenance. A daily flight schedule tells the squadrons how many and what types of sorties are required. The squadrons translate these requirements to specific tail numbers. In the case of fighter and light attack aircraft, the scheduler attempts to balance the sortie requirements between the two squadrons, taking into account any problems a squadron may have with down aircraft. The squadrons compete, each one trying to "outfly" its sister squadron.

All squadrons are similarly organized according to guidelines in the NAMP manual, the "bible" for Naval aviation maintenance. This organizational structure is shown in Fig. B-1. During operations, the appropriate plane captains, There are usually two plane captains per aircraft to provide 24-hour coverage, troubleshooters, and ordnance load crews are positioned on the flight deck to move and arm aircraft and

[1] Although most aircraft, unless refueled from the tanker, can fly for only 1-1/2 hours, the S-3 and E-2 aircraft can be airborne for 3 hours.

respond quickly to any malfunctions. (There are usually two plane captains per aircraft to provide 24-hour coverage.) The troubleshooters are specialists who can diagnose breaks and try to remedy the situation before the aircraft is scheduled for launch. If a break cannot be fixed in time, the aircraft is moved to the side of the flight deck (the "trash" pile) and replaced with a ready aircraft if one is available. Downed aircraft are repaired on the flight deck by O-level personnel or moved, via the elevators, to the hangar deck for repair. The hangar deck is used to repair aircraft, perform scheduled maintenance and corrosion control, and store aircraft when space is tight on the flight deck. Because of space constraints and the large number of aircraft on board the carrier, problems occasionally arise in getting to an available aircraft or in finding a suitable space to do repair work.

A cadre of ship's company personnel support the squadrons' organizational people in their operations. They operate the catapults and recovery devices, move munitions, operate some of the ground support equipment (GSE), and coordinate and oversee the overall flight deck operations. O-level maintenance is basically remove-and-replace. The O-level therefore interacts with the supply system. If a needed component is not available from supply, is not critical to the mission, and does not affect safety of flight, the aircraft will fly with a "hole" in it. Otherwise, an aircraft that is already down or is undergoing scheduled maintenance will be cannibalized or will go to a down status.

The supply system is supported by intermediate level (I-level) maintenance. The Aircraft Intermediate Maintenance Department (AIMD) is made up of a fixed cadre of personnel who provide administrative and control functions, maintain the test equipment and GSE (yellow flight deck gear), and perform some maintenance tasks (oil analysis, NDT). These permanent ship personnel are supplemented by maintenance specialists assigned from the squadrons that the AIMD supports. (Squadrons must also provide support personnel for supply, medical services, food services, laundry, and security.) AIMDs also exist at Naval Air Stations and have similar components of permanent and temporary personnel. The TAD (Temporary Assigned Duty) maintenance personnel from the squadrons are therefore placed where the workload is (carrier or shore). The structure of the AIMDs afloat and ashore is shown in Figs. C-1 and C-2. The *Saratoga* has an allocation of 163 permanent personnel and 230 squadron TAD maintenance men. By comparison, the AIMD at Miramar NAS, the largest AIMD in the Navy, has 530 permanent personnel (of whom about 200 are from the aircraft operational detachment support group) and from 275 to 350 TAD squadron personnel to support approximately 360 aircraft (approximately 250 on station at a given time; the rest are in the depot or are deployed).

Appendix B
ORGANIZATIONAL LEVEL MAINTENANCE

Figure B-1 shows the structure of organizational maintenance, and Table B-1 shows the squadron manpower requirements as reflected by the aircraft's Squadron Manpower Documents (SQMDs). The effect of the decentralized environment can be seen in the number of personnel required in the overhead work centers (OXX). The 187 people shown in Table B-1 contrast to the approximately 30 personnel required for the same work centers in the consolidated Aircraft Intermediate Maintenance Department (AIMD) aboard a carrier.

Effectiveness gains and manpower savings should be realized by adopting some form of consolidation at the organizational level. Proposals for consolidation of organizational duties are not new and have been suggested by outside agencies as well as by the Navy itself. A recent GAO study[1] investigating below-depot-level maintenance in all the services attempted to show the inefficiencies and duplications in the Navy's current organizational structure. A study of compartment requirements for new carriers conducted by the Naval Air Engineering Center[2] recommended investigating the effects of combining two 12-UE fighter or light attack squadrons into one 24-UE squadron. Also, the Navy completed a detailed study[3] in December 1973 on consolidating maintenance for shore-based patrol aircraft squadrons. The results of the "Proposed Reorganization Plan" (PROP) suggested economic advantages in addition to improved products, improved aircraft availability, and improved morale. After evaluating the study, the Navy rejected the suggested new organization. The Navy even suggests a consolidated organizational structure in the NAMP Manual.[4] The structure of this unit, composed of Autonomous Maintenance Units (AMUs) (Fig. B-1) is intended for large readiness and training squadrons or squadrons with multiple aircraft types.

Standard equations for the overhead work centers are shown in Table B-2 along with the manpower requirements for an F-14A and an A-7E squadron.

One form of consolidation is to combine the two 12-aircraft squadrons into one 24-aircraft squadron for the fighter and light attack communities. Such an organization would place all like aircraft under a central control in addition to requiring fewer personnel in many areas. If the two squadrons are combined, the directed manning positions and the fixed portion of the standard equations of Table B-2 should result in

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[1] Productivity *of Military Below-Depot Maintenance—Repairs Less Complex than Provided at Depots—Can be Improved*, Comptroller General of the United States, LCD-75-422, July 29, 1975.

[2] *Aviation Maintenance Facility and Manning Study for CVN-71 Design*, (DILSIE #LD38421A), R. Bruce et al., Naval Air Engineering Center, Lakehurst, N.J., December 1976.

[3] The study originated at Moffett Field Naval Air Station and is mentioned in the above referenced GAO report. However, no documentation has been found describing the study or the test results.

[4] *Naval Aviation Maintenance Program Manual*, OPNAVINST 4790.2a, December 1977.

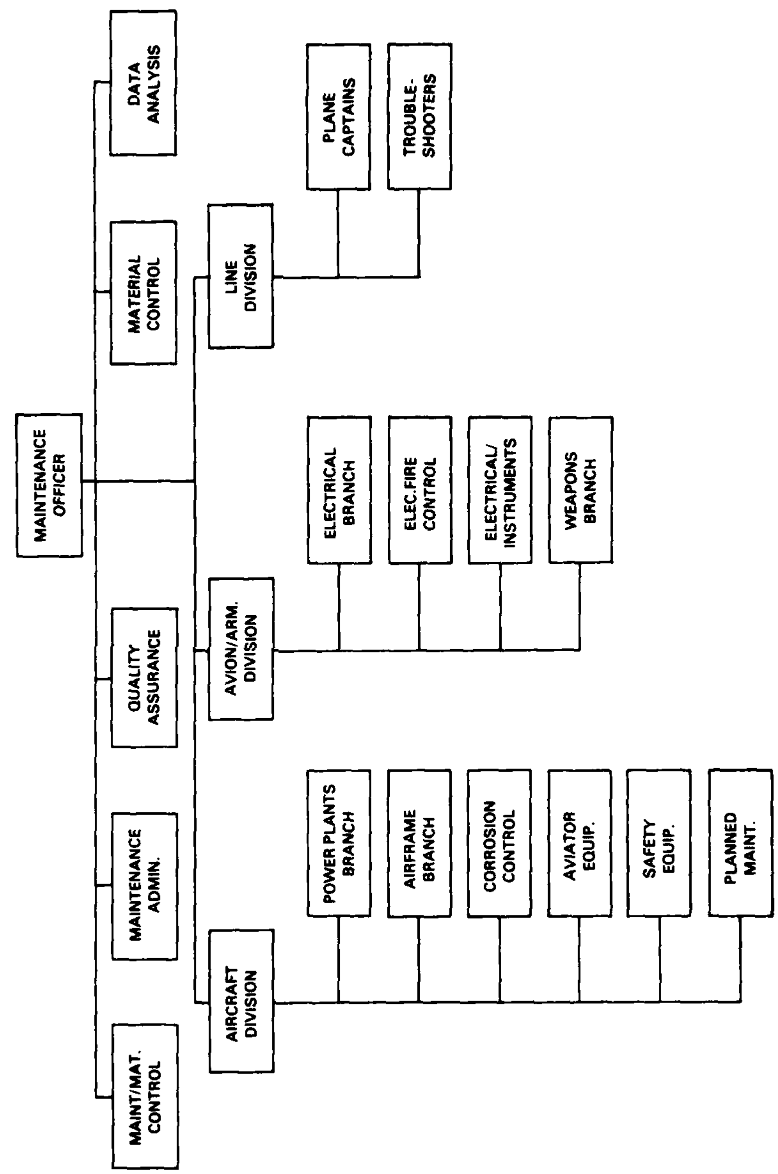

Figure B-1. Navy organizational maintenance structure.

Table B-1.—Organizational manpower requirements of a carrier air wing

Component	F-14A	A-7E	A-6/KA-6	EA-6B	E-2C	S-3A	SH-3H	Total[1]
Number of squadrons	2	2	1	1	1	1	1	9
Number of aircraft	24	24	14	4	4	10	8	38
010 Maintenance off	2	2	1	1	1	1	1	9
020 Maint/mat control	12	14	7	6	6	6	7	58
030 Maint admin	2	2	1	1	1	1	1	9
040 Quality assurance	18	16	9	7	7	8	7	72
050 Material control	8	6	3	2	3	3	3	28
060 Data analysis	2	2	1	1	1	1	1	9
100 Aircraft division	2	2	1	1	1	1	1	9
110 Power plants	30	26	17	8	8	13	8	110
120 Airframe	34	36	21	8	11	19	9	138
121 Corrosion control	18	18	7	4	6	8	4	65
130 Aviators equip	4	8	4	2	1	6	2	27
131 Safety equip	16	14	7	6	3	9	1	56
140 Planned maint	2	4	2	1	0	1	1	11
200 Avionics/arm div	2	2	1	1	1	1	2	10
210 Electronics	28	22	11	17	12	22	11	123
211 Elec fire control	30	28	11	0	0	0	0	69
220 Electrical inst	34	24	14	6	9	23	7	117
230 Armament	28	52	23	2	0	10	6	121
300 Line division	2	2	1	1	1	0	1	8
310 Plane captains	52	54	35	11	10	24	20	206
320 Trouble shooters	10	12	6	5	0	0	0	33
Integrated services[2]	68	52	41	21	19	25	20	246
AIMD[3]	78	56	46	38	22	37	18	295
Total	480	454	270	150	123	219	131	1829

Source: The particular Squadron's Manning Documents. The SQMD includes pilots in the work centers to perform some administrative duties. *The pilots are not included in these numbers.*

[1] Does not include photo/recce squadron.

[2] Personnel assigned to support functions such as supply, mess, and laundry.

[3] Temporary Duty personnel to AIMD.

manpower savings. This effect is realized in the centralized AIMDs and in the large (30 or more UE) Replacement Air Groups (RAGs), or training organizations.

The overhead work centers should not be the only ones affected by a consolidation. Scale should also lessen manpower in the production work centers, if for no other reason than to reduce total supervisory requirements and other Administrative Support hours. Two work centers, indicated by the AMU structure (Fig. B-2), that should realize savings from consolidation are 130, Aviators Equipment and 230, Armament. The majority of the Aviators Equipment Workload[5] is involved with keeping abreast of safety requirements (AS workload). A consolidated squadron should realize a savings of two people for the F-14A and three people for the A-7E. The Armament people maintain the aircraft's ejection racks and upload the munitions. This work center is manned on the basis of the maximum number of load crews required and the average size per load crew. However, minimum manned levels are specified that typically exceed the computed values. That is, the total hours for maintenance and other (AS,

[5] For the F-14A, work center 130 has a weekly PM and CM workload of 12.7 hours of a total 119 hours; for the A-7E, the maintenance workload is 41.3 hours of a total 189 hours.

Table B-2—Overhead work centers manpower requirements methodology

	Work center	Requirements methodology	Number of personnel per squadron F-14	A-7
010	Maint officer	One person assigned	1	1
020	Maint/mat control	People = (No. of shifts + 1) + $\frac{124.6715 + .3652\ (FH)}{\text{Availability}}$	6	7
030	Maint admin	One person assigned	1	1
040	Quality assurance	Eight people of various ratings[1]	9	8
050	Material control	People = $\frac{57.7481 + .3625(FH)(RF)}{\text{Availability}}$	4	3
060	Data analysis	One person assigned	1	1
100	Aircraft division	One person assigned	1	1
140	Planned maint	Number of people is a function of AS workload; typically one person	1	2
200	Avionics/Arm div	One person assigned	1	1
300	Line division	One person assigned	1	1
	Total		26	26

Note: Variables:
FH = flying hours per squadron per week
RF = requisition factor; F-14 = 1.9962, A-7 = 1.2723
Availability at sea = 63 hours per week
Number of shifts on carrier = 2
AS = administrative support

[1]May vary by one or two people because of unique aircraft equipment.

FM, UT) hours are converted to personnel requirements and compared with some minimum manning value. For the F-14A squadron, the hourly data indicate a requirement of 11 people, but 14 per squadron are assigned; for the A-7E, the numbers are 22 and 26. Assuming a consolidated squadron would require only the personnel indicated by the workload, three people for the F-14A and four for the A-7E could be saved. The Aviators Equipment and Armament work centers could therefore require

12 fewer people by combining squadrons. The manpower savings for these work centers and for the overhead work centers are summarized in Table B-3.

Adding a 14 percent factor for support personnel (based on the percentage of integrated services personnel in Table B-1), the total manpower savings would be 65 billets per carrier air wing.

Consolidation may also yield manpower savings in the non-flight deck work centers. However, it is difficult to measure potential savings without a more detailed analysis and a more thorough understanding of the appropriate workloads. It should be noted that the SQMD methodology for determining O-level requirements provides no means for estimating savings due to this kind of consolidation; a revised method would have to be developed. One additional area that would benefit from the consolidated workload is the I-level TAD billets in a squadron (the AIMD values in Table B-1). This area is discussed in detail in Appendix C.

Figure B-2. Organizational level AMU (autonomous maintenance unit) concept.

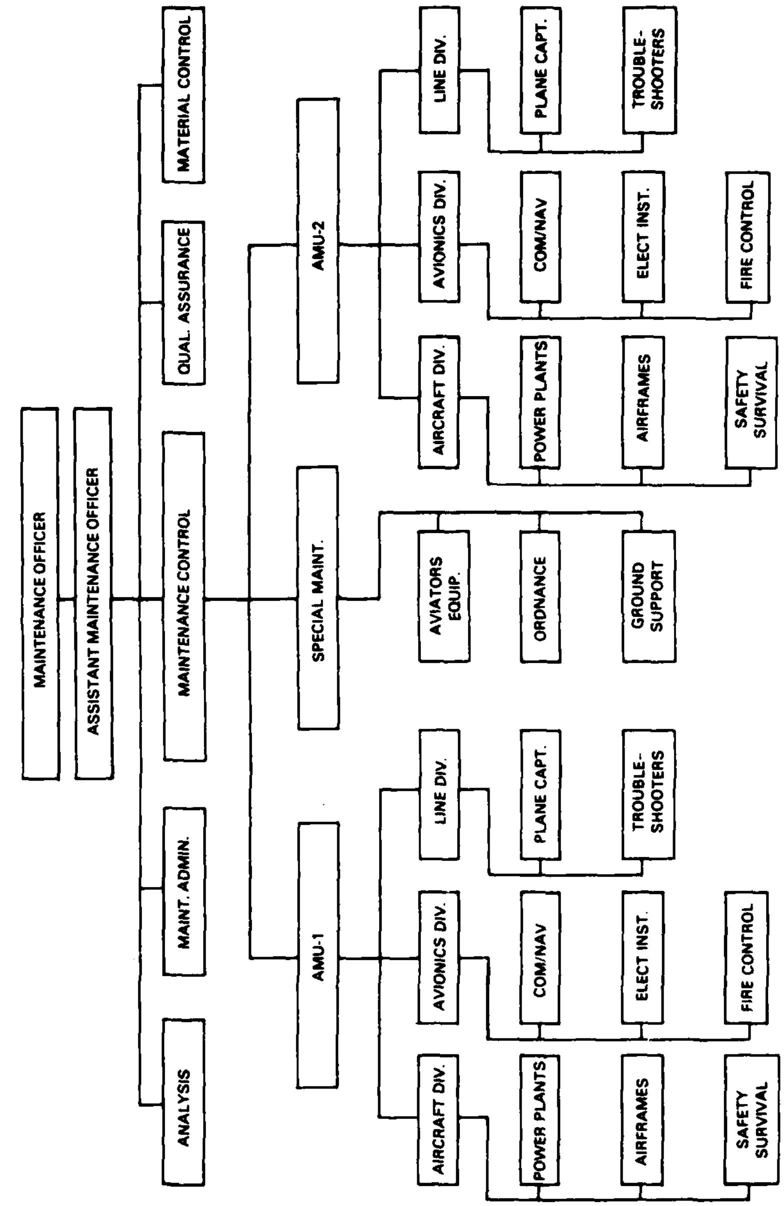

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Table B-3—Work-center manpower savings through squadron consolidation

Work center	F-14A	A-7E	
010	1	1	
020	7	9	
030	1	1	
040	9	8	
050	7	5	
060	1	1	
100	1	1	
130	2	5	
140	1	1	
200	1	1	
230	25	48	
300	1	1	
Total	57	82	per 24-UE squadron
	84	112	for two 12-UE squadrons
	27	30	personnel savings

Appendix C
INTERMEDIATE LEVEL MAINTENANCE: MANPOWER REQUIREMENTS

OVERVIEW

This appendix describes intermediate level maintenance concepts for Naval aircraft as well as manpower requirements determination. Current manpower requirements are compared with those generated from ACM-02,[1] a new requirements determination "model," for the current intermediate maintenance concept and for proposed alternative policies and organizations. These alternatives involve (1) removing some repair actions from the carriers and consolidating them at shore facilities, and (2) estimating manpower requirements for like aircraft squadrons (F-4J, F-14A, A-7E) on the basis of total workload rather than individual squadron workload.

NAVY INTERMEDIATE MAINTENANCE CONCEPT

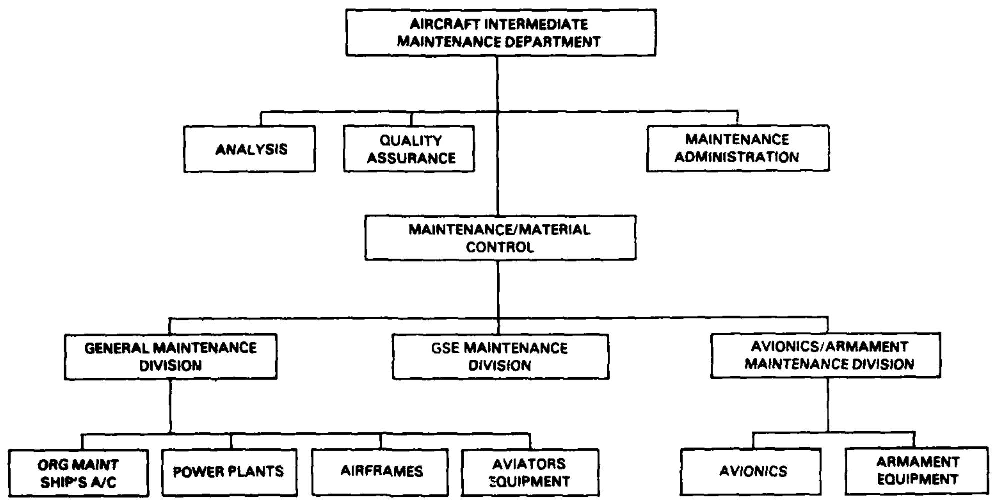
Unlike organizational maintenance, in which operating squadrons are manned and equipped to operate independently, the Navy has attempted to take advantage of their operating environment by centralizing intermediate maintenance aboard aircraft carriers and at Naval Air Stations. The Aircraft Intermediate Maintenance Departments (AIMDs) operate with a fixed component of administrative, planning, and support equipment maintenance personnel augmented by I-level repair specialists temporarily assigned from the individual squadrons that the AIMD supports. I-level maintenance interacts informally with the operational squadrons. Its primary mission is to provide serviceables to the supply system.

Every carrier (CVs and LPHs) and most Navy and Marine Air Stations and Air Facilities have an AIMD capable of repairing components from all the aircraft colocated with it. An AIMD typically comprises seven divisions: Overhead and Administration (OXX), Power Plants (4XX), Airframes (5XX), Avionics (6XX), Armament (7XX), Aviators Equipment (8XX), and Ground Support Equipment (9XX). Each division is composed of numerous shops or work centers, their numbers and types being a function of the size of the AIMD, the type of workload, and the management philosophy of the commanding officer. Some establishments have only 2 or 3 shops in a division, whereas others may have 8 to 10. The organizational structure of AIMDs ashore and afloat is shown in Figs. C-1 and C-2.

The permanent portion of the AIMD fills the overhead and administrative slots (control, analysis, quality assurance, division offices, etc.), mans the Ground Support

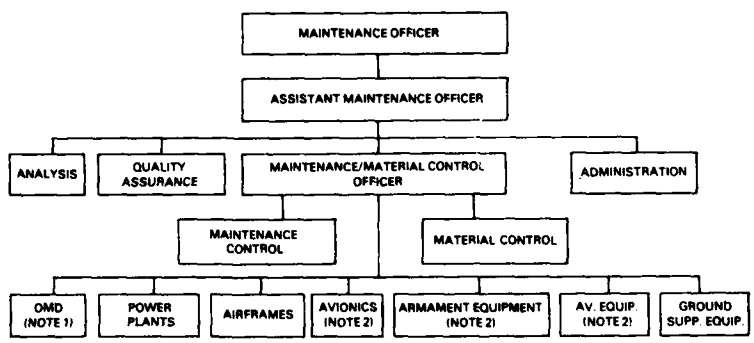
[1] Work *Center Staffing Standards: Aircraft Maintenance—Perform Intermediate Aircraft Maintenance—ACM-02*, NAVMACLANT, January 13, 1978.

Figure C-1. Intermediate level maintenance department organization (afloat).



Reproduced from: OPNAVINST 4790.2A CH-1, June 11, 1974

Figure C-2. Intermediate level maintenance department organization (ashore).



Breakdowns beyond the basic divisions are not illustrated because of the great variety of branches possible. Activities will be required to establish the necessary branches in accordance with their individual requirements. Appendix "D" (Standard Work Center Codes) will be used as a guide to establish branches/work centers within the respective divisions. The following guidelines shall be used as a basis:

(A) Branches should be established only when more than one work center is involved; i.e., JLT engine branch with work centers for J-79 engine and J-52 engine.

(B) Work centers should be established only when a minimum of three men plus a supervisor are required to operate a specific functional area.

Note 1: When specific authority has been granted to combine the OMD and IMA, an organization maintenance division will be established.

Note 2: For Marine Corps activities, officers assigned to these divisions have group duties under the coordination of the group maintenance officer.

Reproduced from: OPNAVINST 4790.2A, Volume I, June 18, 1973

Equipment (GSE) work centers, provides maintenance for support and test equipment, and performs certain other maintenance functions (PME, NDT, VAST). The Temporary Assigned Duty (TAD) personnel from the operating squadrons provide the shop repair capability for the components from the aircraft squadrons they represent. These I-level repair personnel move with the squadron as it transitions from ship to shore and are assigned to the AIMD where the aircraft are located. Conceptually, these personnel move to the location (ship or shore AIMD) where the workload is being generated. Although belonging to a particular squadron, the TAD personnel lose their squadron identity when assigned to an AIMD and will perform maintenance on components from any aircraft or squadron for which they have repair capability.

A carrier AIMD will have requirements for 175 to 200 permanent personnel and approximately 300 TAD personnel. The size of an AIMD at a Naval Air Station will depend on the numbers and types of aircraft assigned. Miramar's AIMD, the largest in the Navy, has approximately 900 people, of whom 325 are TAD from squadrons, 330 are permanent station personnel, and around 200 are permanently assigned from the aircraft operational detachment support group (training squadrons, shore-based aircraft, etc.). Miramar supports approximately 250 aircraft at any given time.

AIMD MANPOWER REQUIREMENTS DETERMINATION

Historically, AIMD personnel requirements have been determined by subjective judgment backed up with a handful of quantitative data. Personnel levels tend to remain constant or increase as new aircraft are added. These requirements estimates are inputs to the Squadron Manpower Document (SQMD) TAD, and each squadron of a given aircraft type has the same number and skill level of personnel. However, the Navy Manpower and Material Analysis Center, Atlantic (NAVMMACLANT) was tasked by the CNO to develop a new model for analytically determining personnel requirements for each AIMD. The model has not yet been implemented[2] within the Navy, and the exact effects on requirements are not known. Initial reactions to ACM-02 are that personnel requirements not only will decrease in quantity, but also will change in terms of grade levels assigned (lower grade levels will result from ACM-02).

The ACM-02 methodology mans the permanently assigned overhead and supervision shops with directed billets (a fixed number of personnel) or with standard equations relating hours to number of aircraft supported. The GSE work centers and certain other production work centers, such as PME, are manned on the basis of the support equipment maintenance workload previously experienced by the AIMD. The production work centers' workload is a function of the number and types of aircraft supported and the support equipment maintenance workload.

Each aircraft in the Navy inventory is assigned a figure for I-level maintenance

[2] ACM-02 is currently going through an update and reevaluation of a number of the factors and equations contained in the model. The factors and resulting manpower requirements given in this appendix are based on the model as it currently exists.

man-hours per month or b-value.[3] This b-value is multiplied by the number of aircraft and summed across all aircraft types to arrive at the total maintenance workload for an AIMD. An aircraft's workload is apportioned to work centers on the basis of its percent contribution to the total workload as observed in historical data. Each AIMD (all carriers are treated the same and coded as CV) has a unique estimate based on its historical data. Support equipment hours are added to the aircraft maintenance hours to arrive at total maintenance workload. Each work center has a support equipment table that lists the hours applicable to each AIMD. Administrative Support (AS) hours are then added to arrive at total workload. AS hours are calculated as a function of maintenance hours, with the function varying for each division. Total workload is then divided by the appropriate availability (shore = 31.9 hours/week; sea = 60 hours/week) to arrive at manpower requirements. Manpower is further broken out by skill levels (NECs) required. The need rather than workload for particular NECs tends to drive manpower requirements in avionics work centers because workloads within NECs tend to be small. The model factors are derived from 3-M data. A year's worth of data are used, and ACM-02 factors are to be updated annually. The b-values are developed from all intermediate maintenance workload, both sea and shore, attributed to a given type of aircraft.

The ACM-02 methodology is intended to determine total requirements for each AIMD. To translate the total requirements to a squadron's TAD personnel, the SQMD analyst computes deployed requirements for each squadron separately and then adds them up to obtain the total TAD requirements. Thus, ACM-02 continues to provide each squadron of a given type of aircraft with the same number and types of personnel as if each squadron is to operate independently of the others.

AIMD PERSONNEL REQUIREMENTS—CURRENT AND ACM-02

Current AIMD personnel requirements, as outlined in the appropriate manpower documents, can be compared with the results of the ACM-02 methodology to highlight the effect of the analytical model. Table C-1 gives these personnel figures for the permanent portion of a number of carrier AIMDs, and Table C-2 shows personnel requirements for the TAD billets of a carrier air wing. The ACM-02 values represent drastic reductions from the requirements as currently stated (approximately 40 percent less for both the permanent cadre and the TAD portion). A number of reasons contribute to this apparently large difference. The ACM-02 requirements for the permanent portion (Table C-1) reflect only aircraft-maintenance-related billets. Additional workload, and therefore additional billets, are required for ship-related functions such as work parties, watch-standing requirements, and the like. These additional billets are not reflected in the ACM-02 values, since separate billets are authorized for these ship-related functions. Apparently, however, since shortages sometimes occur in these kinds of billets, the subjectivity of the current manpower requirements

[3] An aircraft's maintenance man-hours are independent of the flying program, the argument being the lack of a meaningful relationship between flying hours and workload.

method may add billets into the current manpower numbers to cover such shortages. Some observers believe that this subjectivity takes into account the fact that requirements statements are typically not met, and therefore may inflate these requirements accordingly. ACM-02 builds no such slack into its requirements estimation. It is interesting that the ACM-02 requirements are only slightly less (approximately 10 percent) than the current *assigned permanent* AIMD personnel onboard CVs.

The current TAD values in Table C-2 are requirements as stated in the SQMDs. Requirements typically exceed authorizations, which in turn exceed assignments. Again, ACM-02 attempts to predict actual personnel needs without regard to the reality that authorizations and assignments may not meet requirements. This point may account for some of the difference in the values shown in Table C-2. However, the more significant difference is in the statement of particular skill requirements. As will be highlighted shortly, a large number of billets, especially in the Avionics work centers, are driven by the requirement for specific NECs rather than by the actual workload. ACM-02 attempts to compensate for these skill-driven requirements by coding TAD billets with dual NECs. That is, rather than having two billets with separate skills (say, an AT 6606 and an AT 6611), ACM-02 will require only one billet (an AT 6606/6611) if the workload does not justify the two separate billets.

Another point should be mentioned in regard to a squadron's TAD personnel and the number of I-level specialists actually sent to the AIMD. Before a carrier goes on deployment, the AIMD and the squadrons' commanding officers negotiate which people will actually be assigned to the intermediate facility during the cruise. Residual

Table C-1—Permanent carrier AIMD personnel under current method and ACM-02

Carrier Division	Current[1]					ACM-02				
	0XX	4XX, 5XX,8XX	6XX, 7XX	9XX	Total	0XX	4XX, 5XX,8XX	6XX, 7XX	9XX	Total
FORRESTAL	29	38	83	32	182	26	23	27	37	113
SARATOGA	35	35	71	38	173	26	23	27	37	113
INDEPENDENCE	23	46	95	32	196	26	23	27	37	113
AMERICA	33	35	85	48	201	26	25	28	37	116
EISENHOWER	27	45	106	33	211	26	24	28	37	115
KENNEDY	26	41	97	43	207	26	24	28	37	115

[1]Source: Manpower Authorization, OPNAV 1000/2, for appropriate CV.

Table C-2.—TAD personnel requirements for a carrier air wing

Acft	Power plants		Hyd/pneu		Airframes[1]		Avionics		Ordnance		Aviators eqp		Total	
	Curr[2]	ACM-02[3]	Curr	ACM-02	Curr	ACM-02	Curr	ACM-02	Curr	ACM-02	Curr	ACM-02	Curr	ACM-02
F-14A[4]	12	6	6	2	4	4	48	26	4	2	4	4	78	44
A-7E[4]	8	6	2	2	4	2	36	28	4	2	2	2	56	42
A-6/KA-6	4	2	2	1	2	1	36	17	1	1	1	2	46	24
EA-6B	1	1	1	1	1	1	33	17	0	0	2	2	38	22
E-2C	1	1	1	1	1	1	18	11	0	0	1	1	22	15
S-3A	4	3	3	1	3	2	25	12	1	1	2	2	38	21
SH-3H	3	1	2	1	1	1	11	7	0	0	1	1	18	11
Total	33	20	17	9	12	12	207	118	10	6	13	14	296	179

1 Airframes include all the 5XX work centers except Hydraulics/pneumatics.

2 As reported in the squadron's SQMD.

3 The ACM-02 requirements represent an initial exercise of the model based on the current factors and equations.

4 For two squadrons.

TAD personnel not required by the AIMDs often remain with the squadron to perform organizational level functions or are left behind at a shore AIMD. Therefore, an AIMD typically will not require all the TAD personnel assigned to a squadron. This is especially true in the F-14A/F-4J/A-7E communities, since each squadron will have the same number and types of TAD people, with one squadron's personnel often being sufficient to handle the workload of the two squadrons in a carrier air wing.

In summary, ACM-02 suggests that fewer personnel are required in both the permanent and TAD portions of an AIMD than are specified in currently stated requirements. The model uses workload, as reported in the 3-M system, as a basis for these manpower calculations. ACM-02 is a systematic method that in effect defines precisely how manpower requirements are to be estimated. It is likely to have weaknesses, such as inaccuracies of the 3-M inputs to the model, but its strength lies in its ability to communicate precisely how it operates so that identifiable weaknesses can be dealt with. Its reproducibility then makes it a model to be preferred over the more subjective current requirements statements. Its use in this effort to assess alternative policies and organizations seems justified, especially since its logic is reasonable enough and reasonable steps have been taken to assure that the 3-M data used are fairly consistent with observation and interview data. ACM-02 represents a useful step in formulating an analytical model for estimating personnel requirements.

DETAILED INTERMEDIATE MAINTENANCE WORKLOAD

To determine the implications for personnel requirements due to changes in the current intermediate maintenance philosophy, it is necessary to understand the relationship between workload and personnel. Table C-3 shows the AIMD work center workloads for a carrier air wing as defined by the ACM-02 model. These workloads are related to the current and ACM-02 TAD personnel requirements for the non-avionics areas in Table C-4 and for each of the Avionics work centers in Tables C-5 through C-11. The first portion of Tables C-5 through C-11 match the TAD requirements as shown in the SQMDs and as indicated by ACM-02 with the weekly workloads for each type of aircraft. Also given are the Support Equipment Maintenance (SM) and Administrative Support (AS) workloads generated by ACM-02 and the number of permanent personnel in the appropriate work center. The second part of each table breaks an aircraft's total workload into the workload requiring specific skills (NECs). These NEC workloads are matched with personnel requirements. The final part of Tables C-5 through C-11 show the total workload across all aircraft for each NEC.

The ACM-02 model is currently being updated and refined, and the update is likely to affect the maintenance workloads. At this time, however, the only measure of AIMD workload readily available is that defined by the current version of ACM-02. The bottom-line results of the analysis that follows depend, of course, on the workloads that are used in the analysis. However, the skill fragmentation causes such small workloads for many avionics skills that a change in the workload values may indicate only slight changes in resulting manpower requirements.

Table C-3.—ACM-02 definition of AIMD aircraft workload

Item	F-14	A-7E	A-6E	KA-6D	EA-6B	E-2C	S-3A	SH-3H	Total
No. acft (X)[1]	24	24	10	4	4	4	10	8	88
b[2]	243.0	154.3	202.3	156.0	414.4	219.4	223.2	105.5	–
Jet eng	335.2	192.5	74.3	29.7	53.6	21.7	124.9	44.7	876.6
Test cell	37.4	2.3	3.3	0.8	2.4	0	0	0	46.2
Aux fuel st	0.4	61.2	7.9	2.9	0	0	0	0	72.4
Struct	23.7	38.2	17.5	9.5	13.3	4.6	22.0	15.4	144.2
Hyd/pneu	49.0	49.2	20.1	7.9	13.3	9.4	11.4	11.7	172.0
Tire/wheel	56.6	24.6	10.1	3.1	13.3	3.9	20.7	6.4	138.7
NDT	46.0	4.0	3.2	1.1	2.0	2.8	3.5	1.4	64.0
Comm/nav	37.6	99.3	65.5	30.7	40.0	22.8	8.4	44.6	348.9
Elec/inst	24.5	60.3	56.6	27.6	11.2	12.8	12.0	45.0	250.0
Fire control	160.6	102.1	0	0	0	0	0	0	262.7
Radar ECM	56.1	33.7	23.5	7.8	147.3	43.4	15.0	0	326.8
SACE/INS	57.0	133.5	120.6	10.0	45.8	13.6	10.0	0	390.5
VAST	225.6	0	0	0	0	51.2	227.8	0	504.6
ASW	0	0	0	0	0	0	3.2	21.8	25.0
Module repair	108.8	4.3	40.9	6.4	17.2	11.7	18.7	1.5	209.5
Ordnance	60.1	35.6	8.7	2.9	1.8	0	5.4	0	114.5
Parach/float	24.5	6.0	7.8	1.1	8.3	2.6	21.9	1.0	73.2
Escape/envir	14.6	0.6	1.3	0.2	1.5	0.3	1.4	0.2	20.1
LOX	23.6	4.1	4.1	1.8	10.2	0.9	6.8	0	51.5
Total work[3]	1341.3	851.7	465.3	143.5	381.2	201.8	513.3	194.1	4092.2

[1] Theoretical number of aircraft assigned to a carrier.
[2] Monthly I-level workload per aircraft.
[3] Total weekly workload for all aircraft of a given type, model, and series. Total work = (X)(b)/4.348.

The workload values in Tables C-3 through C-11 represent the total aircraft maintenance workload for a carrier AIMD. As carrier air groups transfer to the shore establishments, their workload also transfers from the ship to the shore AIMD. However, the Naval Air Station's AIMD will also receive work from any training, readiness, or nondeployable squadrons located on the base. As noted, for carrier AIMDs, shore-based AIMDs are also expected to have low workloads for avionics NECs, and therefore fewer personnel will be required. The results of the following analysis are therefore somewhat conservative. Consideration of the total workload ashore, as well as afloat, should result in higher personnel savings.

Table C-4.—TAD personnel requirements vs ACM-02 AIMD workload

(Typical carrier air wing)

	Power plants			Hydraulics/pneu			Airframes			Ordnance			Aviator's equip		
Aircraft	Work-load [1]	TAD [2]	ACM-02 [3]	Work-load	TAD	ACM-02	Work-load	TAD	ACM-02	Work-load	TAD	ACM-02	Work-load	TAD	ACM-02
F-14A	373.0	12	6	49.0	6	2	126.4	4	4	60.1	4	2	62.7	4	4
A-7E	256.0	8	6	49.2	2	2	66.8	4	2	35.6	4	2	10.7	2	2
A-6/KA-6	118.9	4	2	28.0	2	1	44.5	2	1	11.6	1	1	16.3	1	2
EA-6B	56.0	1	1	13.3	1	1	28.6	1	1	1.8	0	0	20.0	2	2
E-2C	21.7	1	1	9.4	1	1	11.3	1	1	0	0	0	3.8	1	1
S-3A	124.9	4	3	11.4	3	1	46.2	3	2	5.4	1	1	30.1	2	2
SH-3H	44.7	3	1	11.7	2	1	23.2	1	1	0	0	0	1.2	1	1

[1] Total hours per week for all aircraft of the type, model, and series.
[2] Current TAD requirements from the aircraft's SQMD.
[3] ACM-02 TAD requirements.

IMPLICATIONS OF TRANSFERRING I-LEVEL WORKLOAD

The DRMS study recommends that the Navy consider transferring a portion of the I-level repair action from CVs to shore-based AIMDs. Such a strategy offers savings in the number of personnel required because of economies of scale, and an increase in personnel productivity. The measures of productivity increase are discussed in the main body of the report. This appendix deals only with the issue of personnel savings due to consolidation.

As can be seen from Tables C-5 through C-11, many personnel in the Avionics work centers have weekly workload demands far short of a full workweek. This is primarily caused by the many different aircraft types and the high degree of skill fragmentation both within and across aircraft systems. The personnel implications of consolidating some carrier repair actions at a centralized shore AIMD arise from the potential of combining multiple small workloads so that a few people can handle them, instead of the many personnel across the carriers. Of course, the level of personnel savings is a function of which repair actions are transferred and the corresponding workload for those repair actions.

Table C-5—Communications/navigation shop workload and manpower requirements (Typical CV)

a. By aircraft type

Aircraft	Weekly workload (man hours)	TAD requirements Current	TAD requirements ACM-02
F-14A	37.6	12	6
A-7E	99.3	10	10
A-6E	65.5	8	5
KA-6D	30.7		
EA-6B	40.0	8	4
E-2C	22.8	5	5
S-3A	8.4	3	2
SH-3H	44.6	6	3
Total	348.9	52	35

Note: SM hours = 44.6
AS hours = 3.1
Total workload = 426.6
Permanent party:
Current 7 to 10
ACM-02 7 to 10

Table C-5—Communications/navigation shop workload and manpower requirements (Typical CV) (cont'd)

b. By aircraft type and NEC

Acft	NEC	Weekly workload (man hours)	TAD requirements	
			Current	ACM-02
F-14	ET 1447	.9	0	0
	AT 6604	1.0	0	0
	AT 6605	1.5	0	2[2]
	AT 6607	.1	2	2[1]
	AT 6609	15.1	2	2
	AT 6611	9.4	4	2[1]
	AT 6612	5.8	4	2[2]
	other	3.8	0	0
A-7E	ET 1447	.8	0	0
	AT 6604	0	0	0
	AT 6605	15.7	0	2
	AT 6607	2.1	2	2[1]
	AT 6608	.1	0	0
	AT 6609	10.7	0	2
	AT 6611	21.9	2	2[1]
	AT 6612	18.6	2	2
	AT 6617	20.9	2	2
	other	8.5	2	0
E-2C	ET 1447	.1	0	0
	AT 6604	.1	0	0
	AT 6605	0	0	1
	AT 6606	2.7	1[1]	1
	AT 6607	0	1[1]	1[2]
	AT 6609	2.5	1	1[1]
	AT 6611	9.6	1	1[2]
	AT 6612	2.8	1	1[1]
	AT 6633	0	1	1
	other	5.0	0	0
A-6E/ KA-6D	ET 1447	.6	0	0
	AT 6604	46.0	3	1[1]
	AT 6605	16.8	1	1[2]
	AT 6606	16.2	1	1[3]
	AT 6607	1.7	1	1[2]
	AT 6608	2.4	1	1
	AT 6609	.2	0	1
	AT 6611	4.7	0	1[1]
	AT 6612	0	1	1[3]
	other	7.6	0	0
EA-6B	ET 1447	.4	0	0
(EX-CAP)	AT 6604	21.9	0	1[1]
	AT 6605	4.2	1	1
	AT 6606	6.8	1	1[2]
	AT 6607	.4	1	1[3]
	AT 6609	.1	1	1[1]
	AT 6611	2.8	2	1[3]
	AT 6612	0	1	1[2]
	other	3.4	1	0
S-3A	ET 1447	.3	0	0
	AT 6604	0	0	0
	AT 6605	.3	0	0
	AT 6607	.4	1[2]	1[2]
	AT 6608	0	0	0
	AT 6609	4.5	2[1]	1[1]
	AT 6611	.3	1[2]	1[2]
	AT 6612	.9	2[1]	1[1]
	other	1.7	0	0
SH-3H	ET 1447	.4	0	0
	AT 6605	2.4	1	1[1]
	AT 6606	5.2	1	1[2]
	AT 6608	8.9	1	1[1]
	AT 6609	5.8	0	1[3]
	AT 6611	10.3	1	1[2]
	AT 6612	5.5	1	1[3]
	other	6.1	1	0

Note: 0 indicates a workload of less than .05 hours a week.
[1,2,3]Dual coded NEC, letters match the double codes.

Table C-5—Communications/navigation shop workload and manpower requirements (Typical CV) (Cont'd)

c. By NEC across aircraft types

NEC	Weekly Workload (man hours)	NEC description
ET 1447	3.5	Communication Security Devices Equip. (KY-28) Tech
AT 6604	69.0	Integrated COMM/NAV/IFF IMA Tech
AT 6605	40.9	Aircraft Navigation Equipment IMA Tech
AT 6606	30.9	Aircraft Doppler Radar Navigation IMA Tech
AT 6607	4.7	Digital Data Link Communication IMA Tech
AT 6608	11.4	Aircraft Navigation Computers IMA Tech
AT 6609	38.9	Aircraft Electronic Identification (IFF) IMA Tech
AT 6611	59.0	Aircraft Communication Equipment IMA Tech
AT 6612	33.6	Aircraft TACAN Maintenance IMA Tech
AT 6617	20.9	APN-190 Doppler Radar Nav. & APM-341(V) PGSE Tech
AT 6633	0	Communication Security Devices Equip. (KG-23) Tech

In the absence of a very detailed analysis, some simplifying assumptions can be made in order to roughly estimate the personnel implications of consolidating I-level repair actions. Assuming that a workload of less than 10 hours per week (as defined by ACM-02) results in transferring a skill, Tables C-12 through C-18 show, for the various work centers, the personnel implications of consolidation. The top portion of the tables shows the billets that would remain on the carrier. Given are the skill requirements (NECs), the workloads as defined by ACM-02, the current TAD requirements from SQMDs, and the so-called theoretical requirements calculated by dividing workload by availability (60 hours/week). This issue will be discussed in more detail in the following section.

The second part of Tables C-12 through C-18 shows the billets that are transferred to shore AIMDs. Again shown are NECs, current requirements, and workload. Also shown are the workload for six carriers[4] and the theoretical requirements (using an availability of 31.9 hours per week) for the consolidated workloads. The results are summarized below:

[4] The use of six carriers represents either the Atlantic or Pacific Fleet. This is a simplifying assumption in that not all carriers will have the same type, model, and series of aircraft. This assumption should only marginally affect the results.

Table C-6—Electrical instrument shop workload and manpower requirements (Typical CV)

a. By aircraft type

Aircraft	Weekly workload (man hours)	TAD requirements Current	TAD requirements ACM-02
F-14A	24.5	4	2
A-7E	60.3	4	2
A-6E	56.6	5	2
KA-6D	27.6		
EA-6B	11.2	2	1
E-2C	12.8	1	1
S-3A	12.0	1	1
SH-3H	45.0	2	1
Total	250.0	19	10

Note: SM hours = 29.0
AS hours = 23.6
Total workload = 302.6
Permanent party:
Current 6 to 11
ACM-02 5 to 8

Table C-6.—Electrical instrument shop (cont'd).

b. By aircraft type and NEC

Acft	NEC	Weekly workload (man hours)	TAD requirements Current	TAD requirements ACM-02
F-14	AE 7149	12.5	4	2
	other	12.0	0	0
A-7E	AE 7109	0	0	0
	AE 7133	3.1	[1]	[1]
	AE 7171	8.4	2	2
	other	48.8	2	0
A-6E/	AE 7133	1.5	2	1
KA-6D	other	82.7	3	1
EA-6B	AE 7105	1.3	1	1
	other	9.9	1	0

Acft	NEC	Weekly workload (man hours)	TAD requirements Current	TAD requirements ACM-02
E-2C	AE 7105	2.0	1	0
	AE 7109	0.1	0	1
	other	10.7	0	0
S-3A	AE 7175	0.6	1	1
	other	11.4	0	0
SH-3H	AE 7105	2.5	0	1[2]
	AE 7109	0.9	0	0
	AE 7144	6.1	2	1[2]
	other	35.5	0	0

Note: 0 indicates workload of less than 0.05 hours per week.

[1] Both current and ACM-02 requirements list one 7133/7116 per squadron; 7116 is an INS repairman and is counted in the SACE/INS shop.

[2] Dual coded NECs; letters match the double codes.

Table C-6.—Electrical instrument shop (cont'd)

c. By NEC across aircraft types

NEC	Workload (man hours/week)	NEC description
AE 7105	5.8	ASN-50/ASN-73 Attitude Heading Reference System IMA Tech
AE 7109	1.0	Loft Bomb Computer Set (AJB-3A) AFRS IMA Tech
AE 7133	4.6	ASA-32 (AFCS) ASN-54 (APCS) IMA Tech
AE 7144	6.1	Helicopter ASE/AFCS IMA Tech
AE 7149	12.5	ASN-92 Navigation Maintenance Tech
AE 7171	8.4	CP-953 ADC and AJM-32 SSE IMA Tech
AE 7175	.6	S-3A Electrical Systems IMA Tech

Table C-7—Fire control shop workload and manpower requirements (Typical CV)

a. By aircraft type

Aircraft	Weekly workload (man hours)	TAD requirements: Current	TAD requirements: ACM-02
F-14A	160.6	8	8
A-7E	102.1	10	8
Total	262.7	18	16

Note: SM hours = 49.4
AS hours = 23.6
Total workload = 335.7
Permanent party:
Current 6 to 8
ACM-02 5 to 9

b. By aircraft type and NEC

Aircraft	NEC	Weekly workload (man hours)	TAD requirements: Current	TAD requirements: ACM-02
F-14A	AQ 7984	155.8	0	2
	7985, 7986		4	2
	7988, 7989		0	2
	7991 or		2	1
	7992		2	1
	Other NEC	4.8	0	0
A-7E	AQ 7921	20.4	4	2
	AQ 7975	52.5	6	2
	AQ 7976	14.0	0	2
	AT 6603	9.9	0	2
	Other NEC	5.3	0	0

c. By NEC across aircraft types

NEC	Workload (man hours/week)	NEC description
AT 6603	9.9	ASN-99 Projected map display set & ASM 398 PGSE Tech
AQ 7921	20.4	AVQ-7 HUD IMA Tech
AQ 7975	52.5	APQ-126 FLR IMA Tech
AQ 7976	14.0	C-8185 ASCU & tactical computer (ASN-91) IMA Tech
F-14	155.8	AWG-9/AWM-23 (Phoenix) IMA Tech

Table C-8—Radar/ECM shop workload and manpower requirements

a. By aircraft type

Aircraft	Weekly workload (man hours)	TAD requirements	
		Current	ACM-02
F-14A	56.1	2	4
A-7E	33.7	4	4
A-6E	23.5 }	3	2
KA-6D	7.8 }		
EA-6B	147.3	16	8
E-2C	43.4	4	1
S-3A	15.0	6	3
Total	326.8	35	22

Note: SM hours = 28.2
AS hours = 28.4
Total workload = 383.4
Permanent party:
Current 6 to 8
ACM-02 6 to 7

Table C-8—Radar/ECM shop workload and manpower requirements (cont'd)

b. By aircraft type and NEC

Acft	NEC	Weekly workload (man hours)	TAD requirements	
			Current	ACM-02
F-14	AT 6639	14.4	0	2
	AT 6643	38.4	2	2
	other	3.3	0	0
A-7E	AT 6639	8.4	2	2
	AT 6641	21.0	2	2[1]
	AT 6643	0	0	2[1]
	AT 6646	0.1	0	0
	other	4.2	0	0
S-3A	Any NEC	15.0	1	1
	AT 6614	–	3	1
	AT 6615	–	2	1

Acft	NEC	Weekly workload (man hours)	TAD requirements	
			Current	ACM-02
A-6E/KA-6D	AT 6639	9.7	1	1
	AT 6641	15.3	0	1[1]
	AT 6643	1.8	2	1[1]
	other	4.5	0	0
E-2C	AT 6616	35.5	3	1
	AT 6646	0.2	[2]	[2]
	other	7.7	1	0
EA-6B	AT 6643	11.1	1	1
	AT 6644	0	1	1
	AT 6647	105.8	2	2
	AT 6666	11.9	2	1
	other	18.5	10	3

Note: 0 indicates a workload of less than .05 hours a week.

[1] Dual coded NEC; letters match the double codes.

[2] Current and ACM-02 list an AT 6633/6646; this billet is counted in COMM/NAV shop.

Table C-8—Radar/ECM shop workload and manpower requirements (cont'd)

c. By NEC across aircraft types

NEC	Workload (man hours/week)	NEC description
AT 6616	35.5	APS-120 Radar IMA Tech
AT 6638		Passive Detection Equipment Tech
AT 6639	32.5	ALR-45/ALR-50/ALR-54 ECM IMA Tech
AT 6641	36.3	ALQ-126 ECM IMA Tech
AT 6643	51.3	ALQ-81/ALQ-100/ALQ-126 EMC IMA Tech
AT 6644	0	DECM (AN/ALQ-55 or 92) IMA Tech
AT 6646	0.3	ALQ-91/ALQ-108 DECM IMA Tech
AT 6647	105.8	ALQ-99 ECM Jammer/Xmtter & ALM-107 Test Console IMA Tech
AT 6648		ALQ-99 ECM Receivers/and ALM-109/108 Test Console IMA Tech
AT 6666	11.9	Central Computer (AN/AYA-6) Tech
AT 6667	-	EA-6B ALQ-99 Displays and Recording System Tech

Table C-9—SACE/inertial navigation shop workloads and manpower requirements (Typical CV)

a. By aircraft type

Aircraft	Weekly workload (man hours)	TAD requirements	
		Current	ACM-02
F-14	57.0	4	2
A-7E	133.5	8	4
A-6E	120.6	20	8
KA-6D	10.0		
EA-6B	45.8	7	4
E-2C	13.6	5	3
S-3A	10.0	4	1
Total		48	22

Note: SM hours = 102.2
AS hours = 37.8
Total workload = 530.5
Permanent party:
Current 8 to 10
ACM-02 8 to 10

Table C-9—SACE/inertial navigation shop workloads and manpower requirements (Typical CV) (cont'd)

b. By aircraft type and NEC

Acft	NEC	Weekly workload (man hours)	TAD requirements	
			Current	ACM-02
F-14A	AE 7149	47.8	[1]	[1]
	other	9.2	4	2
A-7E	AE 7116	93.8	2	2
	AE 7128	23.0	4	2
	other	16.7	2	0
EA-6B	AT 6623	0.1	0	0
	AE 7132	3.2	1	1
	AQ 7963	23.4	3	1
	AQ 7964	6.3	1	1
	other	12.8	2	1
S-3A	AE 7149	5.1	0	1
	other	4.9	4	0
A-6E/	AE 7112	27.1	2	1
KA-6D	AE 7132	6.9	2	1
	AQ 7953	28.2	4	1
	AQ 7954	11.6	3	1
	AQ 7961	0	0	0
	AQ 7963	3.2	0	0
	AQ 7964	19.3	2	1
	other	34.3	7	3
E-2C	AE 7132	1.9	1	1
	AE 7149	9.4	1	1
	other	2.3	3	1

Note 0 indicates a workload of less than 05 hours a week

[1] Current requirements list 2, and ACM 02 requirements list 1 AE 7149 per squadron, these billets are counted in Electrical Instruments shop

Table C-9—SACE/inertial navigation shop workloads and manpower requirements (Typical CV) (cont'd)

c. By NEC across aircraft types

NEC	Workload man hours/week	NEC description
AT 6623	.1	ASA-27 SACE Test Bench IMA Tech
AT 6631	0	ASM 122/144 and Onboard Memory Tester IMA Tech
AE 7112	27.1	ASN-31/ASN-36 Inertial Navigation System IMA Tech
AE 7116	93.8	ASN-90 Inertial Measurement Set IMA Tech
AE 7128	23.0	A-7 AFCS IMA Tech
AE 7132	12.0	ASW-15/ASW-16 AFCS & ADC IMA Tech
AE 7149	62.3	ASN-92 Navigation Maintenance Tech
AQ 7953	28.2	APQ-148 Radar & OA-3736/ASM-77 Modified IMA Tech
AQ 7954	11.6	ASQ-133 Ballistic Computer and Computer System Test Console
AQ 7955	–	APM-225 Module Analyzer Test Console IMA Tech
AQ 7961	0	ASQ-61A Ballistic Computer and ASM-308 Test Bench IMA Tech
AQ 7963	26.6	APQ-92/APQ-129 Search Radar SACE Console IMA Tech
AQ 7964	25.6	AVA-1 Analog Display Indicator and Test Console IMA Tech
AQ 6655	–	TS-2109 and TS-2110/ASA-48 SACE Programmer
AQ 6651	–	ASM-347 (GT-1) SACE Programmer/Maintenance Tech

Table C-10—VAST shop workload and manpower requirements by aircraft (Typical CV)

Aircraft	Weekly workload (man hours)	TAD requirements: Current	TAD requirements: ACM-02
F-14A	225.6	18	4
E-2C	51.2	3	1
S-3A	227.8	10	4
Total	504.6	31	9

Note: SM hours = 108.3
AS hours = 47.3
Total workload = 660.2
Permanent party:
Current 7 to 28
ACM-02 6 to 11
All aircraft require an
AT 6652 – VAST operator

Table C-11—Antisubmarine warfare shop workloads and manpower requirements (Typical CV)

a. By aircraft type

Aircraft	Workload man hours/week	TAD requirements Current	TAD requirements ACM-02
S-3A	3.2	1	1
SH-3H	21.8	3	3
Total	25.0	4	4

Note: SM hours = 0.6
AS hours = 4.7
Total workload = 30.3
Permanent party:
Current 2
ACM-02 1

b. By aircraft type and NEC

Aircraft	NEC	Workload man hours/week	TAD requirements Current	TAD requirements ACM-02
S-3A	AX 6526	1.5	1	1
	AX 6527	0	0	0
	Other	1.7	0	0
SH-3H	AX 6526	1.0	0	1
	AX 6527	13.0	2	1[1]
	AX 6529	2.4	1	1[1]
	AX 6564	1.4	0	1
	Other	4.0	0	0

Note: 0 indicates a workload of less than .05 hours a week.
[1] Dual-coded NEC; letters match the double codes.

c. By NEC across aircraft types

NEC	Workload man hours/week	NEC description
AX 6526	2.5	Aviation ASW (MAD) Tech
AX 6527	13.0	Aviation ASW (Airborne Sonar) IMA Tech
AX 6529	2.4	ASW JULIE ASA 20/26 and Sonobuoy ARR-52/58
AX 6564	1.4	OPTI/AQH-1/4 Acoustic System IMA Tech

Table C-12—Communications/navigation shop billets remaining afloat and ashore (6 carriers) in the current and consolidated structures

Billets remaining/carrier

Aircraft	NEC	Current req.	Workload (man hours/week)	Theo. req.
F-14A	AT 6609	2	15.1	1
A-7E	AT 6611	2	21.9	1
	AT 6612	2	18.6	1
	AT 6617	2	20.9	1
A-6/KA-6	AT 6604	3	46.0	1
	AT 6605	1	16.8	1
	AT 6606	1	16.2	1
SH-3H	AT 6611	1	10.3	1
EA-6B	AT 6604	0	21.9	1
Total		14		9

Billets removed

Aircraft	NEC	Current req.	Workload (man hours/week)	6 × Workload	Theo req.
F-14A	AT 6607	2	.1	.6	1
	AT 6611	4	9.4	56.4	2
	AT 6612	4	5.8	34.8	2
A-7E	AT 6607	2	2.1	12.6	1
	AT --	2	8.5	43.0	2
A-6/KA-6	AT 6607	1	1.7	10.2	1
	AT 6608	1	2.4	14.4	1
	AT 6612	1	0	0	0
EA-6B	AT 6605	1	4.2	25.2	1
	AT 6606	1	6.8	40.8	2
	AT 6607	1	.4	2.4	1
	AT 6609	1	.1	.6	1
	AT 6611	2	2.8	16.8	1
	AT 6612	1	0	0	0
	AT --	1	3.4	20.4	1
E-2C	AT 6606/07	1	2.7	16.2	1
	AT 6609	1	2.5	15.0	1
	AT 6611	1	9.6	57.6	2
	AT 6612	1	2.8	16.8	1
	AT 6633	1	0	0	0
S-3A	AT 6607/11	1	.7	4.2	1
	AT 6609/12	2	5.4	32.4	1
SH-3H	AT 6605	1	2.4	14.4	1
	AT 6606	1	5.2	31.2	1
	AT 6608	1	8.9	53.4	2
	AT 6612	1	5.5	33.0	1
	AT --	1	6.1	36.6	2
		38			
Total	(38 × 6) = 228		vs.		31

Table C-13—Electrical/instrument shop billets remaining afloat and ashore (6 carriers) in the current and consolidated structures

Billets remaining/carrier

Aircraft	NEC	Current req.	Workload (man hours/week)	Theo. req.
F-14A	AE 7149	4	12.5	1
A-7E	AT 6621	2	48.8	1
SH-3H	AE 7144	2	45.0[1]	1
A-6/KA-6	AE --	3	82.7	2
Total		11		5

[1]Represents the total workload for the SH-3H.

Billets removed: none

Aircraft	NEC	Current req.	Workload (man hours/week)	6 × Workload	Theo req.
A-7E	AE 7171	2	8.4	50.4	2
A-6/KA-6	AE 7133	2	1.5	9.0	1
EA-6B	AE 7105	1	1.3	7.8	1
	AE --	1	9.9	59.4	2
E-2C	AE 7105	1	2.0	12.0	1
S-3A	AE 7175	1	.6	3.6	1
		8			
Total	(6 × 8) = 48		vs.		8

Table C-14—Fire control shop billets remaining afloat and ashore in the current and consolidated structures

Billets remaining/carrier

Aircraft	NEC	Current req.	Workload (man hours/week)	Theo req.
F-14A	AQ 7985	2	160.6	1
	AQ 7986	2		1
	AQ 7991	2		1
	AQ 7992	2		1
A-7E	AQ 7921	4	20.4	1
	AQ 7975	6	52.5	1
Total		18		6

Billets removed: none

Table C-15—Radar/ECM shop billets remaining afloat and ashore (6 carriers) in the current and consolidated structures

Billets remaining/carrier

Aircraft	NEC	Current req.	Workload (man hours/week)	Theo. req.
F-14A	AT 6643	2	38.4	1
A-7E	AT 6641	2	21.0	1
A-6/KA-6	AT 6641	0	15.3	1
EA-6B	AT 6643	1	11.1	1
	AT 6647	2	105.8	2
	AT 6666	2	11.9	1
E-2C	AT 6616	3	35.5	1
Total		12		8

Billets removed

Aircraft	NEC	Current req.	Workload (man hours/week)	6 × Workload	Theo req.
A-7E	AT 6639	2	8.4	50.4	2
A-6/KA-6	AT 6639	1	9.7	58.2	2
	AT 6643	2	1.8	10.8	1
EA-6B	AT 6644	1	0	0	0
	AT 6654	2			1
	AT 6674	2			1
	AT 6648	2	18.5	111.0	1
	AT 6667	2			1
	AT 6675	1			1
	AT 6676	1			1
E-2C	AT --	1	7.7	46.2	2
S-3A	AT 6614	3			2
	AT 6615	2	15.0	90.0	1
	AT --	1			0
		23			
Total	(6 × 23) = 138		vs.		16

Table C-16—SACE/inertial navigation shop billets remaining afloat and ashore (6 carriers) in the current and consolidated structure

Billets remaining/carrier

Aircraft	NEC	Current req.	Workload (man hours/week)	Theo. req.
A-7E	AE 7116	2	93.8	2
	AE 7128	4	23.0	1
	AE 7133	2	16.7	1
A-6/KA-6	AE 7112	2	27.1	1
	AQ 7953	4	28.2	1
	AQ 7954	3	11.6	1
	AQ 7964	2	19.3	1
	AQ 6655	1		1
	AQ 7955	3		1
	AQ 6651	1	34.3	1
	AQ 7196	1		1
	AQ 7112/7132	1		0
EA-6B	AQ 7963	3	23.4	1
Total		29		13

Billets removed

Aircraft	NEC	Current req.	Workload (man hours/week)	6 × Workload	Theo req.
F-14A	AE 7173	4	9.2	55.2	2
A-6/KA-6	AE 7132	2	6.9	41.4	2
EA-6B	AE 7132	1	3.2	19.2	1
	AQ 7964	1	6.3	37.8	2
	AE 7173	1	12.8	76.8	2
	AT 7955	1			2
E-2C	AE 7132	1	1.9	11.4	1
	AE 7149	1	9.4	56.4	2
	AT 6631	1			0
	AE 7196	1	2.3	13.8	1
	AE 7173	1			1
S-3A	AE 7196	1			1
	AT 6628	1	10.0	60.0	0
	AT 6619	2			1
	AE 7149	0			0
		19			
Total	(6 × 19) = 114		vs.		18

Table C-17—VAST shop billets remaining afloat in the current and consolidated structures

Billets remaining

Aircraft	NEC	Current req.	Workload (man hours/week)	Theo. req.
F-14A	AT 6652/53	18	225.6	4
E-2C	AT 6652/53	3	51.2	1
S-3A	AT 6652/53	10	227.8	4
Total		31		9

Billets removed: none.

Table C-18—ASW shop billets remaining afloat and ashore (6 carriers) in the current and consolidated structures

Billets remaining

Aircraft	NEC	Current req.	Workload (man hours/week)	Theo req.
SH-3H	AX 6527	2	13.0	1

Billets removed

Aircraft	NEC	Current req.	Workload (man hours/week)	6 × Workload	Theo. req.
S-3A	AX 6526	1	1.5	9.0	1
SH-3H	AX 6529	1	2.4	14.4	1
		2			
Total	(6 × 2) = 12		vs.		2

The above personnel savings are theoretical in some ways, but they suggest the possibility of large gains.[5] Also, the values are for the TAD Avionics personnel for six carriers. Permanent personnel, non-avionics TAD personnel, and the remaining carriers are not included.

[5] If ACM-02 requirements were used as the starting point rather than SQMD requirements, the personnel implications would not be so large; the current requirements for six carriers would be 708 versus 1242 and the personnel savings for a fleet would be 327.

SQMD statement of avionics TAD requirements for 6 carriers	1,242
Personnel remaining on 6 carriers after consolidation	306
Personnel moved to shore AIMDs for consolidated workload	75
Manpower savings for 6 carriers	861

Squadron TAD Requirements

The foregoing kind of consolidation is not constrained by the current practice of manning each squadron of a given type of aircraft with the same number and types of TAD personnel. For the fighter and light attack communities, this practice appears to result in an overstatement of manpower requirements. The following discussion is intended to provide some sense of the manpower savings discussed in the previous paragraphs, which can be attributed to the change in the current practice of estimating squadron requirements independently of one another.

In a number of areas, the TAD personnel assigned to one squadron are sufficient to handle the workload generated by the two squadrons assigned to a carrier. For example, the weekly workload in the Hydraulics/Pneumatics work center for an F-14A squadron is 24.5 hours. This workload indicates a requirement for one TAD billet, but there are two—one each for the two F-14A squadrons in a carrier air wing—even though a single billet could handle the combined workload of 49 hours. The extent of this apparent overstatement in TAD requirements is shown for the non-avionics area in Table C-19.

Table C-19 uses the workload as defined by ACM-02 to calculate theoretical requirements (workload divided by personnel availability) in each of the non-avionics work areas. To avoid problems due to possible understatement of workload, theoretical personnel requirements are also calculated, based on twice the workload indicated by ACM-02. Compared with the current TAD requirements for the F-14A and A-7E, there may be an overstatement of up to 30 personnel (30 - 11 + 20 - 9).

In the Avionics work centers, most TAD requirements are driven by skill demands rather than actual workload. The F-14 SQMD lists eleven different avionics skills independent of those required in the VAST shop. One person at each skill level is sufficient to cover the total workload of the two F-14 squadrons. These eleven skills plus four personnel in the VAST shop (based on the 225.6 hours of work) suggest that fifteen people is the minimum number required for the F-14 avionics workload. If the ACM-02 workload were doubled, only 22 personnel would be required (the eleven skills plus 8 in the VAST shop plus an extra AE7149, AT6643, and an AQ for the Fire Control Shop).

Using the above logic for the A-7 squadrons, fifteen personnel are required for the avionics workload indicated by ACM-02 (5 in the Comm/Nav shop, 2 each in the

Table C-19—F-14 and A-7 AIMD ACM-02 workload (non-avionics)

Area	F-14A Work-load[1]	F-14A Theo. req.[3]	A-7E Work-load[1]	A-7E Theo. req.	F-14A Work-load[2]	F-14A Theo. req.	A-7E Work-load[2]	A-7E Theo. req.
Power plants	373.0	6	256.0	4	746.0	12	512.0	9
Hydraulic/pneu	49.0	1	49.2	1	98.0	2	98.4	2
Airframes	126.4	2	66.8	2	252.8	4	133.6	3
Ordnance	60.1	1	35.6	1	120.2	2	71.2	2
Aviators eq	62.7	1	10.7	1	125.4	2	21.4	1
Total:								
Theoretical		11		9		22		17
Current		30		20		30		20
ACM-02		18		14		18		14

[1] ACM-02 weekly workload for two 12-UE squadrons.

[2] Twice weekly workload for two 12-UE squadrons.

[3] Theoretical requirements = workload/60.

Electrical Instrument and Radar/ECM shops, and 3 each in the Fire Control and SACE/INS shops). Doubling the ACM-02 workload leads to a requirement for seventeen personnel (the above plus an AE7116 and an AQ7975). These avionics billets (15 and 22 for the F-14 and 15 and 17 for the A-7) can be added to the (theoretical) non-avionics numbers of Table C-19 to show the personnel required for consolidated squadrons. The total requirements are summarized in Table C-20.

Table C-20.—F-14A and A-7E TAD requirements.

Requirements	F-14A	A-7E	Total
Current	78	56	134
ACM-02	44	42	86
Consolidated[1]	26	24	50
Consolidated[2]	44	34	78

[1] Based on ACM-02 workload; requirements from Table C-19 plus 15 billets in avionics shops for both the F-14A and A-7E.

[2] Based on twice the ACM-02 workload; requirements from Table C-19 plus 22 billets for the F-14A and 17 for the A-7E in the avionics shops.

Appendix D
IMPACT OF IMPROVED REENLISTMENT RATES

SUMMARY

The analysis in this appendix presumes that sea duty is partly responsible for the current low reenlistment rates of technical I-level shipboard ratings. Therefore, we expect that reenlistment rates would improve if the majority of the technical ratings were moved from shipborne AIMDs to centralized, shore-based AIMDs. This would be especially likely if such centralization permitted manning ship AIMDs exclusively with volunteers, or the remaining ship AIMDs were so small a proportion of the total force that sea duty would become a rare event.

This appendix provides some rough estimates of the payoff that improved retention would yield to the Navy. To make the estimates, we substituted the second-term reenlistment rate for the Training Device (TD) rating as the second-term rate for the Aviation Electrician (AE), Fire Control (AQ), and Electronics (AT) ratings. The TD rating is a highly technical rating that is almost exclusively shore-based. Second term reenlistment rates similar to that for the Training Devices rating have also been noted (Table D-5) for I-level specialties in the Air Force.

The following four tables summarize this appendix. Table D-1 contains current reenlistment statistics. Table D-2 summarizes the expected reduction in recruitment and training of first-term ratings. Table D-3 summarizes the expected reduction in training for advanced courses. Table D-4 indicates the expected increase in skilled technicians (those with more than eight years service) that result from improved second-term reenlistment rates.

INTRODUCTION

The analysis in this appendix presumes that sea duty is partly responsible for the current low reenlistment rates of technical I-level shipboard ratings, and that sea duty therefore would improve those rates. This appendix provides rough estimates of the likely effect on reenlistment rates if the majority of shipboard AIMD activity were centralized at shore-based AIMDs.

First, current authorizations and reenlistment rates are described for several technical I-level ratings, along with reenlistment rates for comparable Air Force skills. Second, the assumptions used in subsequent computations are discussed. Third, there is a description of a simple flow model used to compute changes in Naval personnel as a result of changing reenlistment rates. Last, the payoff resulting from improved reenlistment rates is computed.

Table D-1—Navy reenlistment rates by selected ratings through August FY1978

Rating	Authorized personnel	Reenlistment rate First-Term	Reenlistment rate Second-term
AE	8,800	.25[1]	.45
AQ	3,327	.38	.24
AT	11,656	.64	.37
TD	2,102	.83	.62

Sources: MAPMIS Report 1133-4229, PERS-212 CREO management report, and CNO enlisted requirements plan.

[1] Contains six-year obligated tour lengths. Actual first-term rate is lower.

Table D-2—Reduction in recruiting and technical training loads for selected ratings

Rating	Current	With higer reenlistments	Reduction	Percent reduction
AE	1,386	1,283	103	7
AQ	503	399	104	21
AT	1,240	1,030	210	17
Total	3,129	2,712	417	13

CURRENT STATISTICS

The first three rows of Table D-1 above list the authorizations and reenlistment rates for the major AIMD ratings:

Table D-3—Reduction in advanced training loads for selected ratings

Rating	Current	With higher reenlistments	Reduction	Percent reduction
AE	347	321	26	7
AQ	191	152	39	20
AT	793	659	134	17
Total	1,331	1,132	199	15

Table D-4—Proportion of selected ratings with more than 8 years service

Rating	Current	With higher reenlistments	Percent improvement
AE	.21	.27	33
AQ	.17	.34	100
AT	.30	.42	40
Total	.25	.35	40

- Aviation Electricians (AE)
- Fire Control (AQ)
- Electronics (AT)

These ratings account for 23,783 authorized personnel attached exclusively to Naval aviation; all possess highly specialized skills. The fourth row of Table D-1 is the Training Devices (TD) rating, which is also a highly specialized and technical rating, but is almost exclusively shore-based. Notice that both first- and second-term TD reenlistment rates are significantly higher than the sea-duty-oriented ratings.

Table D-5 presents reenlistment statistics from the Air Force for technical specialties that are similar to the AE, AQ, and AT ratings.

Table D-5.—Air Force reenlistment rates (first 9 months of FY 1978)

Air Force Speciality (code)	Reenlistment rate First-term	Reenlistment rate Second-term
Defensive fire control (321xx)	.35	.51
Integrated avionics comp (326xx)	.27	.62
Flight control & instruments (325xx)	.28	.60
Avionics navigation (328xx)	.36	.63
Electrical (423xx)	.43	.74

Source: HQ USAF/MPC Report RCS PMC-P630, *Reenlistment Rates Air Force Wide.*

The first-term Air Force reenlistment rates are not much different from those of the Navy. This leads to a mixed conclusion. Although Naval personnel specialists would expect decreased sea duty to improve first-term reenlistment rates, there is insufficient evidence from this cursory examination to estimate the improvement. In any event, the large majority (about 75 percent) of first-term AE, AQ, and AT personnel serve in O-level tasks. Thus, whatever the reenlistment effect from reducing I-level sea duty through centralizing AIMD work ashore, the impact on first-term reenlistment would be small. The subsequent analysis makes the conservative assumption that first-term reenlistment rates will not change.

The case with second-term reenlistment appears much clearer. Because the second-term reenlistment rate for the shore-based AT rating and for all four Air Force ratings are in close agreement, one can accept the hypothesis that reduced sea duty will increase second-term reenlistment rates. In the subsequent analysis, the TD second-term reenlistment rate of .62 is substituted for the reenlistment rates of the AE, AQ, and AT ratings.

COMPUTATIONAL ASSUMPTIONS

The following assumptions are made in the subsequent analyses:

1. Sea duty contributes to low AE, AQ, and AT second-term reenlistment rates. This is a hypothesis attributed to Naval personnel specialists and appears to have support in both Navy and Air Force data.

2. Shore-based AIMDs would absorb a large majority of shipborne AIMD work, thus reducing sea duty requirements. It is further assumed that seaborne AIMD work is so small a proportion of total AIMD work that all AIMD billets at sea can be filled by volunteers or rotated among all personnel, so that sea duty becomes a rare event. Thus, for all practical purposes, personnel would view I-level work as a shore-based activity.
3. The second-term reenlistment rates of the AE, AQ, and AT ratings would rise, approaching that of the TD rating.
4. The improved second-term reenlistment rate is considered to apply to all personnel in the rating, even though some (less that 25 percent) may eventually go to O-level ship-based billets. This assumption views those O-level assignments, even when added to the ship AIMD work, as still representing a small proportion of the total shore-based billets in the rating.
5. The impact of changing reenlistment rates can be reflected by a simple, steady-state, manpower flow model.

SIMPLIFIED MANPOWER FLOW MODEL

To see the payoff in changes to the second-term reenlistment rates, we must construct some model of the process. Modeling accessions and manpower flow in a career field is a difficult problem. One should account for the dynamics in the process, such as increases or decreases in authorizations over time and variations introduced by various attrition factors (e.g., reductions in force can induce cross-training). Since our purpose is merely to provide some indication of the payoff of changed reenlistment rates, we employ a simple steady-state flow model. The absolute results that the model provides are not to be expected in actuality, since the model compares the world as if it were in a steady state (e.g., smooth flow—no dynamics) operating under current reenlistment rates and the same steady-state world operating under the changed rates. A career field is rarely in a steady state, of course, but this modeling method will reveal the effect of changing the reenlistment rate in isolation from all the other factors that influence personnel flow.

Simple steady-state balancing equations can be developed for this model by merely assuming that the total authorized personnel will not change with reenlistment rate. This is a very conservative assumption, because if higher reenlistment rates are expected, then the ratings will have more people with higher levels of experience; and because higher levels of experience usually mean higher productivity, the expectation is that authorized strength can be reduced. While this analysis does not employ such estimates of increased productivity, readers of this report should be aware that possible reductions in authorized strength can accrue from improved reenlistment rates.

PAYOFF FROM IMPROVED SECOND-TERM REENLISTMENT

The model was used to estimate payoff in three areas.

First, it estimated the reduction in recruitment and training of first-termers. Simply stated, if fewer personnel leave at the end of the second term, then fewer need to be recruited. The results of the model are shown in Table D-2. The overall weighted reduction is 13 percent. Thus, fewer dollars need to be spent in recruitment activities and training of first-termers, because fewer are required.

Second, the model estimated the reduction in second-termers going to advanced I-level courses during the fourth to the eighth year of enlistment. That reduction was 15 percent and represents a straight reduction in training slots at those advanced schools. The reductions for each rating are shown in Table D-3.

Third, the model estimated changes in the experience level of the force (Table D-4). Overall, the experience level of the force grows by 40 percent through a change in reenlistment rate. The proportion of personnel with more than eight years service increases from 25 to 35 percent. This argues that such a force is more capable and productive, and thus more effective.

Appendix E
MAINTENANCE AND SUPPLY PERFORMANCE EXPLORATIONS: AN S-3A EXAMPLE

This appendix presents the results of some initial analytical explorations into the performance implications of the problems faced by the current maintenance and supply structure. It also presents relative performance comparisons of the current structure and those structural alternatives suggested in the main body of this report. Two such alternatives were explicitly addressed: that of moving some component repair from the ship to a shore-based repair facility, and that of moving some depot repair to the same facility.

These analyses should be regarded as preliminary, not exhaustive. The intent is to provide sufficient analysis and a relevant methodological approach to warrant further investigation into these alternative structures. Given this purpose, only data for the S-3A were explored.

REVIEW OF CURRENT PROBLEMS

The primary problem focus in the main body of this report has been on issues of scale and the impact of small scale on effectiveness. The typical measure of effectiveness for that discussion has been the availability of mission-capable aircraft, or more specifically, the percentage of non-mission-capable aircraft caused by lack of spare parts i.e., Non-Mission Capable due to Supply (NMCS). This measure reflects not only the amount of spare parts (stock levels) on the ship, but also the ability of the maintenance organization to repair broken parts promptly.

Possible causes for the observed NMCS rates have been discussed in the main body of the report, but a brief review is warranted here. Three primary reasons have been suggested to explain why computed stock level requirements have not been met. The first and most obvious is lack of sufficient funding, particularly during the early stage of weapon system procurement. The second is the long procurement lead time problem, which suggests that when new required levels are established it takes a long time, through the budget and procurement processes, to fill these new requirements. Neither of these problems will be addressed directly in this analysis. The third reason, which this analysis does address, concerns the inefficiencies introduced because of the small scale of the operation.

Another possible cause of shortages is underestimation of the stock level requirements themselves during initial provisioning. Typically, mean times between failures (MTBF) are overstated, and repair cycle times (RCT) are underestimated, both of them being based on optimistic engineering estimates. Awaiting parts times (AWP), although considered explicitly in initial provisioning computations, also add significantly to total component repair times. For example, data provided by the Naval Aviation Supply Office (ASO) that were used for S-3A requirements computations until recently,[1] indicated that the average repair cycle time (excluding AWP) of components was approximately 6 days, while data from the maintenance organizations (3-M data) indicated that actual experience showed times of 9 to 10 days. Experience also showed AWP times of an additional 5 to 7 days, making a total repair time of 14 to 17 days. This means that much more stock is required to fill those longer repair pipelines than was anticipated in the requirements computations. This, in turn, causes shortages that result in increased NMCS rates.

The analysis that follows will address only the repair cycle times and AWP times: MTBF issues, although affected by the small scale of operations, will not be addressed despite their obvious importance.

There are a number of causes for the long AWP times in addition to those discussed above (MTBFs and RCTs). The small scale of the operation, given current requirement computation methods, yields zero stock level requirements for many low-demand items. This is especially true of bit-and-piece parts (B&P) required to repair shop replaceable assemblies (SRAs). This means that even though they are low demand items, demands will always occur for some of them and immediately cause an AWP condition. Stowage space and managerial burdens may also limit the range of parts stocked aboard ship. Clearly, not all items required to fix all components can be put on one ship, especially when it supports six to seven aircraft types. This limited range of parts has a "ripple" effect on AWP. Typically, for S-3A components, an SRA requires two to five bits and pieces in order to accomplish repair. If one of those parts is not on the ship, then the SRA is AWP. In turn, if that SRA is required to repair a weapon replaceable assembly (WRA), the WRA is also AWP.

The long repair cycle times may be caused by a number of scale problems. The limited scale of the operation makes it difficult to batch process a number of like items at one time. For the automatic test equipment (ATE) in particular, this means that an ATE-setup time penalty has to be paid for every item that is repaired. There may also be limitations in the availability of test equipment which, in turn, causes severe queuing.

The accessibility of repair parts may also contribute to the longer times. Typically, parts are not stowed in areas or in ways convenient to the location where the repair is being accomplished. It therefore takes time to obtain a necessary part, and test equipment is tied up until the part arrives.

AWP impacts WRA repair times. It can potentially double the test time required. If, during the course of a WRA test, an SRA is required but is not available (AWP), then the test must be stopped. The failed SRA must then be removed from the WRA and repaired. If the SRA is repaired on the same equipment, then the WRA must be removed, the test equipment reconfigured (set up) for the SRA, the SRA tested and repaired, the test equipment reconfigured for the WRA, and the WRA retested. Even if the SRA were not tested using the same equipment, the WRA would typically be

[1] We understand that soon after the DRMS receipt of data for the study, the S-3A data base was updated to reflect the longer times. Given that the system is currently facing these shortages and our purpose is to demonstrate the effects of long RCTs and AWP, as well as compare alternative structures, this update should not have an adverse impact on the analysis.

taken off so the equipment could be used for another component. The reconfiguring of the equipment and the retest would still have to occur.

The remainder of this appendix discusses how these issues affect the current structure and how certain alternative structures might improve matters. An analytical methodology will be presented in the next section. This will be followed by an analysis of the current structure that will demonstrate the impact of some of the issues reviewed here and establish a baseline case. The final section describes the alternative structure and compares it with the baseline case.

EVALUATION METHODOLOGY—MODEL

The supply portion of the S-3A case study was performed using a dynamic queuing model of shipboard and shore-based repair. That is, mathematical expressions were derived describing the average number of components in the various parts of the supply pipeline: ship repair, depot repair, transportation, etc., *as a function of time.* With this description of the pipeline quantities, it was then possible to compute measures of performance, such as the number of components backordered and an approximation to the number of aircraft NMCS. Of key importance was the fact that measures were computed and shown as a function of time. Traditional analysis of supply performance has usually concentrated on more limited queuing results called the "steady state" performance. Steady-state measures are usually simpler, computationally more tractable, and probably sufficient for the investigation of peacetime performance. In this analysis we have been interested in the potential performance of the alternative structures under *wartime* conditions, and therefore have made the additional effort to model and compute the measures under wartime dynamics such as the transition to wartime flying rates and pipeline interruptions.

The scope and time period of the analysis has been limited and a limited modeling approach was necessary. Aspects of the problems which have been included in the model are:

- Exponentially distributed interarrival times for component failures.
- Exponentially distributed repair times.
- Indentures of components to the third level (bits and pieces).
- Multi-echelon repair.
- Time-dependent failure and repair processes.
- Full cannibalization at the aircraft level.

Aspects of the problem which have not been included are:

- Lateral resupply and distribution control to the ship.
- Cannibalization at the WRA level.
- Failure-dependent repair processes (limited server queuing, batching, repair priority, etc.).

- Mission essentiality of components.
- Aspects of transportation beyond average transportation time.

Clearly, any further study of alternative structures for the Navy should look into the influence of these aspects. In most cases, their omission from our study tended to favor the current structure. For example, consideration of repair queuing due to personnel or test equipment limitations would probably degrade the current shipboard repair process more than the larger-scale Aircraft Intermediate Maintenance Department (AIMD) operations suggested in the alternatives. Also, a larger shore-based AIMD exercising real time distribution control of serviceable components to the ships it supports under these alternatives would probably perform better than indicated in our study, where we have prohibited such control. Cannibalization at the WRA level for SRAs would mitigate the loss of SRAs in the current structure, but the opportunities for such cannibalization would be much higher at a large shore-based AIMD. We have considered the loss of any WRAs in our list to cause a loss of mission capability when no replacement part is available. To determine exactly what this loss in capability is, it is necessary to know the mission essentiality of each component. It is also necessary to know the alternative missions available and desired in a scenario to determine the effect of that loss in mission capability. In the absence of this information we have compared all alternatives using the NMCS measure, giving all WRA components equal mission essentiality.

Transportation limitations due to finite capacity, availability of transport, and scheduling have not been considered directly in the analysis; instead we have lumped all of these effects into an average transportation delay for resupply. However, in certain scenarios we have stopped all transportation and observed the effects.

The following section describes the dynamic queuing model.

Components in Resupply

If we know the number of components in repair and in the depot resupply pipeline, we can couple it with knowledge of the serviceable stock on hand to determine performance measures, such as the backorders on parts that have no serviceable replacements and NMCS aircraft after shortages have been consolidated (cannibalization).

Let

$\bar{F}(s,t)$ = probability that an element entering repair at time s is still in repair at time t, and

$m(t)$ = mean number of components entering repair (failing) at time t.

under the following assumptions:

1) Repair time distribution is independent of the failure process;
2) The failure process is Poisson;
3) $\bar{F}(s,t)$ is a measurable function of s for a fixed t;
4) $\bar{F}(s,t)$ is a nonnegative distribution and $F(s,t) = 0$ if $t<s$

for a given component the number in repair at time t has a Poisson distribution with mean

$$\lambda(t) = \int_0^t \bar{F}(s,t)m(s)ds$$

That is, the probability of i units in repair is $\frac{\lambda(t)^i e^{-\lambda(t)}}{i!}$

For example, suppose that at time τ we change to a wartime state and change the failure rate and average repair rate. Then

$$m(s) = \begin{cases} \lambda_1 & s \leqslant \tau \\ \lambda_2 & s > \tau \end{cases}$$

$$\bar{F}(s,t) = \begin{cases} e^{-\frac{t-s}{T_1}} & s \leqslant t \leqslant \tau \\ e^{\frac{t-s}{T_1}} e^{-\frac{t-\tau}{T_2}} & s \leqslant \tau < t \\ e^{\frac{t-s}{T_2}} & \tau < s \leqslant t \end{cases}$$

And,

$$\lambda(t) = \begin{cases} \displaystyle\int_0^t \lambda_1 e^{-\frac{t-s}{T_1}}\, ds & t \leq \tau \\ \displaystyle\int_0^\tau \lambda_1 e^{-\frac{\tau - s}{T_1}}\, e^{-\frac{t-\tau}{T_2}}\, ds + \int_\tau^t \lambda_2 e^{-\frac{t-s}{T_2}}\, ds & t > \tau \end{cases}$$

$$\lambda(t) = \begin{cases} T_1 \lambda_1 \left(1 - e^{-\frac{t}{T_1}}\right) & t \leq \tau \\ T_1 \lambda_1 \left(1 - e^{-\frac{\tau}{T_1}}\right) e^{-\frac{t-\tau}{T_2}} + T_2 \lambda_2 \left(1 - e^{-\frac{t-\tau}{T_2}}\right) & t > \tau \end{cases}$$

Note that if $t >> \tau$ we have the usual result, $\lambda(t) = T_2\lambda_2$. The importance of this expression lies in the fact that dynamic scenarios can be represented. It is possible to consider such effects as phased buildup of wartime activity, attrition, temporary stand-down, and repair interruptions.

It is also true that if failures occur according to a nonhomogeneous Poisson process and each failure has a probability f_i of going to a particular repair facility i, then the number of components in that facility is Poisson distributed, with mean

$$\lambda_i(t) = \int_0^t \bar{F}_i(s, t) f_i m(s) ds$$

Consequently, each repair "pipeline" can be treated as an independent nonhomogeneous Poisson process in which each distribution of repair time, $\bar{F}_i(s, t)$, can be a different function of time. Note also that since each is an independent Poisson process, the total number in all repair pipelines has a Poisson distribution with mean

$$\lambda(t) = \sum_{i=1}^{N} \lambda_i(t), \quad \text{N facilities}$$

Indentured Components

The Navy currently performs shipboard repair of WRAs and SRAs. It was important to know the effect of the availability of SRA spare components to fix the WRAs, as well as the effect of availability of bit-and-piece (B&P) spares to fix the SRAs. For example, if bits and pieces to repair certain SRAs were in short supply, then SRA repair could not proceed. If spare stock in those SRAs had been provided under the assumption of SRA repair and the repair was inhibited, shortages of SRA spares would quickly cause the WRAs to go unrepaired as well. This ripple effect due to lack of components at the lowest level of indenture could quickly increase the number of NMCS aircraft.

Our approach to indentured components was to consider the effect of shortages of SRAs as an additional delay in WRA repair time, that is, the AWP was added to the average WRA repair period. In turn, the AWP time for bits and pieces was added to the SRA repair time. Consider first the AWP time due to SRAs. Let $\lambda_{ij}(t)$ be the mean number of SRA j components in repair, where the SRAs considered belong to WRA i, and let there be M_i SRAs in total associated with WRA i. The average backorders of the jth SRA are given by

$$BO_{ij}(t) = \sum_{k=S_{ij}+1}^{\infty} (k - S_{ij}) \frac{\lambda_{ij}(t)^k e^{-\lambda_{ij}(t)}}{k!}$$

and represent the average shortages of that SRA as a function of time. To estimate the average delay experienced on each SRA we divided the backorders by the arrival rate of SRA failures. Let $\gamma_{ij}(t)$ represent this arrival rate. Then the average AWP time incurred due to the jth SRA, when it fails, is

$$T_{A_{ij}}(t) = \frac{BO_{ij}(t)}{\gamma_{ij}(t)}$$

and the probability that the jth SRA fails when the ith WRA fails is approximated by

$$\frac{\gamma_{ij}(t)}{\Gamma_i(t)}$$

where $\Gamma_i(t)$ is the average failure rate of the ith WRA. The average AWP time for that WRA is then obtained by averaging across the various SRAs $j = 1, \ldots M_i$ weighted by the respective conditional failure probabilities. That is,

$$T_{A_i}(t) = \sum_{j=1}^{M_i} \frac{\gamma_{ij}(t)}{\Gamma_i(t)} \frac{BO_{ij}(t)}{\gamma_{ij}(t)}$$

This is the time added to the average WRA repair cycle time to obtain the total average repair time.

Note that this approach and derivation requires the assumptions of:

(1) No more than one SRA failure per WRA failure (otherwise $\gamma_{ij}(t)/\Gamma_i(t)$ could exceed 1)
(2) Total demand rate for SRAs to be less than the demand rate of the parent WRA (otherwise

$$\sum_{j=1}^{M_i} \frac{\gamma_{ij}(t)}{\Gamma_i(t)} > 1 \text{).}$$

These assumptions do not always hold true in practice, and in this study several WRA families of SRAs violated (1) or (2) or both. Our approach in this case was to truncate the SRA family to satisfy assumption (2) and throw out any SRA violating assumption (1). This again created a more favorable situation for the current structure, since its performance was more dependent on AWP times. With the inclusion of the additional SRAs, the current structure's performance would have worsened relative to the alternative structures.

The approach for B&Ps (the second indenture) was similar to that for the SRAs. We computed the B&P AWP time based on B&P backorders and demand rate and added this time to the SRA repair cycle time. However, since no B&P failure data relative to parent SRAs was available, we could only demonstrate the *possible* ripple effect of AWP times due to B&Ps by assuming certain B&P failure rates. Based on discussions with Navy personnel we made the following assumptions purely for demonstration purposes:

(1) Each SRA has five piece parts.
(2) The failure rate of each part is one-fifth the parent SRA failure rate.

This estimate is conservative for the case in which failures of one or two piece parts dominate within the B&P family associated with an SRA when resupply is interrupted since the higher demand would more quickly lead to shortages of B&Ps and consequent AWP time. Given that the current structure is affected more by B&P AWP time relative to the alternatives presented, this assumption also favors the current structure.

Measures of Performance

Given the average number of components in various repair pipelines, and a spare stock level, it is possible to measure the effect of supply shortages on squadron performance. The three measures computed in this analysis are the *fill rate*, *average backorders*, and *NMCS* aircraft. The fill rate measures the likelihood of not having demands in excess of serviceable components; it is expressed by

$$FR(t) = \sum_{i=o}^{s} \frac{\lambda(t)^i \, e^{-\lambda(t)}}{i!}$$

where (t) is the previously derived mean number of components in repair as a function of time, and s is the serviceable stock level for the component.

The average backorders of a component represent the expected shortages of that component which cannot be filled with spare stock and ultimately represent a "hole" or degraded capability of the aircraft. This is given by

$$BO(t) = \sum_{i=s+1}^{\infty} (i - s) \frac{\lambda(t)^i e^{-\lambda(t)}}{i!}$$

$$= \lambda(t) - s + \sum_{i=o}^{s} (s - i) \frac{\lambda(t)^i e^{-\lambda(t)}}{i!}$$

The total expected backorders are obtained by summing the average backorders of each WRA component.

Fill rate and expected backorders measure performance on a component-by-component basis. A measure closer to operational performance measurement is the NMCS level, which reflects the effect of supply performance on aircraft availability. For this study we computed the average number of NMCS aircraft after cannibalization to minimize the number of airframes affected by component shortages. We assumed an idealized complete cannibalization in which the smallest number of aircraft is affected at all times. Under this assumption the probability that the number of airframes in the NMCS state is j or less is the same as the joint probability that the number of shortages on each WRA component type is j or less. That is,

$$P_{NMCS_j} = \text{Probability (NMCS} \leq \text{j)} = \prod_{i=1}^{M} \text{Probability (Failures of } i^{th} \text{ component} \leqslant s_i + j - 1)$$

where M is the number of WRA component types. The expected NMCS for N aircraft is then

$$\text{ENMCS(t)} = \sum_{j=o}^{N} j \text{ Probability (NMCS = j)}$$

$$= \sum_{j=1}^{N} (1 - P_{NMCS_j})$$

In this analysis each measure is computed as a function of time, given the mean number of components in repair, (t).

Computational Approach

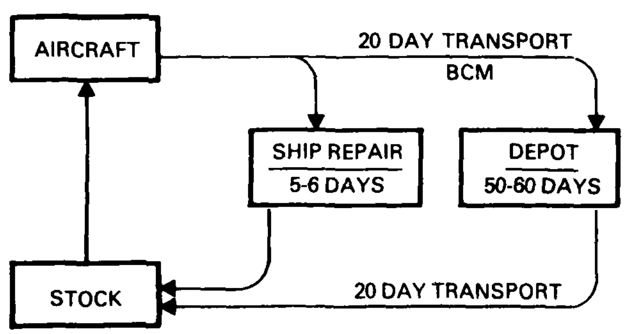
The analytic use of the foregoing models involved defining a structure (for supply and repair support), reading ASO data describing the failure and repair statistics of each WRA and its associated SRA and B&P components, determining initial spare stock levels by emulating Navy stockage policies, and measuring the performance of a deployed S-3A squadron by computing the above measures as a function of time under certain scenarios. The scenarios included operations at peacetime demand rates, peacetime demand extrapolated to wartime flying rates, and resupply cutoff from CONUS repair facilities.

CURRENT STRUCTURE DESCRIPTION: BASELINE CASE

This section describes the assumptions made about the current S-3A component supply and repair structure and the computed performance of that structure using the previously described methodology. It should be emphasized that this is computed performance only; it depends strongly on the assumptions made and the S-3A supply data provided by the ASO.

Figure E-1 illustrates the "pipeline" characteristics of the assumed current structure. Failed aircraft components, WRAs, and SRAs are repaired on ship when possible and at a shore-based depot otherwise. The latter repair operation incurs about a 40-day round-trip transportation time, plus a depot repair time that averages 50 to 60 days. In the meantime, when serviceable stock is available aboard ship, a component is replaced on the aircraft from that stock. The important parameters affecting performance are the ship and depot repair times (these were provided by the ASO data), Beyond Capability of Maintenance (BCM) rates (also provided in the ASO data), transportation time (averages provided by the Navy), and the stock levels provided for each component (computed by emulating Navy stockage policy). The repair times and transportation times determine how long a component will be in a given repair pipeline and consequently unavailable for use. The BCM rate identifies the percentage of components that enter a given pipeline. If this rate is high, many components enter the depot pipeline and are unavailable for a longer time than if they are repaired on the ship. The quantities of components in these pipelines must be "covered" by providing spare serviceable components aboard ship. If too few are provided, aircraft will go into NMCS states while repair is completed or items are ordered and shipped from the depot.

Figure E-1—Current structure pipeline



Stockage Assumptions

In stocking this model of the current structure, we attempted to approximate the Navy requirements calculations for the Aviation Consolidated Allowance List (AVCAL) and pipeline stock. We used peacetime daily demand rates extrapolated to wartime flying rates and used repair cycle times[2] and BCM rates provided in the

[2] Recent experience indicates that the repair cycle times reflected in the data understate what is actually required by four to five days; however, Navy provisioning has not yet accommodated these longer repair times. We have therefore reflected current shortages by provisioning against the times given in the data.

ASO-supplied S-3A data. For the shipboard repair pipeline we provided spares at a 90 percent fill rate. That is, given the shipboard repair time, percentage of off-ship repair (BCM), and expected wartime daily demand rate for each WRA and SRA, we provided the serviceable stock level such that the probability of demands in excess of serviceable stock was less than 0.1. A zero stock level was determined when the probability of having no demands over the pipeline time was at least 0.9. For the fraction of items entering the longer depot repair pipeline, we provided 90 days of serviceable stock plus an order and ship time (OST) safety level.[3] The OST safety level was determined by computing the fraction of items in the depot pipeline, computing the stock level required for the OST pipeline time, and subtracting this from the stock level to give a 90 percent fill rate for the depot OST pipeline time. That difference gave the level of OST safety stock and was added to the 90-day protection stock.

In the following analysis we assume that a ship starts with its full authorized stock, computed as described above. Furthermore, we assume that all of this stock is serviceable and is prepositioned on the ship at the time of deployment. Obviously, this assumption is idealistic, because some components will not be provided at the full authorized level because of inadequate initial provisioning, higher condemnation rates than expected, lags in production, or the inability to free enough components from the various pipelines. Shortages of components will affect all structures investigated and should be a subject of any further investigation of structure alternatives.

Prepositioning components at the ship maximizes the performance of the shipboard squadron since minimum delay is encountered in providing a serviceable component at the aircraft. In doing this, however, we have assumed that pipelines to the depot and in shipboard repair are empty. This means the maximum delay will be encountered initially in the repair and transport of failed components. This assumption seemed reasonable in view of the fact that components are generally in short supply and it is not likely that *both* pipelines and authorized serviceable stock would be full in the event of wartime deployment. The filling of repair pipelines and depletion of shipboard serviceables can be seen in the analysis by observing performance results at various points in time after deployment.

Our stockage calculations may deviate from Navy provisioning methods, but we believe deviations in the amount of stock computed will be small. Furthermore, since we compare all structures at the same total stock cost, these deviations will affect all structures by about the same amount.

S-3A Current Structure Performance

Figure E-2 illustrates the performance of the current structure with respect to the NMCS rate as a function of time of deployment. The peacetime performance curve indicates about a 10 percent NMCS rate (10 percent of aircraft are non-fully-mission capable after cannibalization) after day 60. Initially, the NMCS rate is lower because

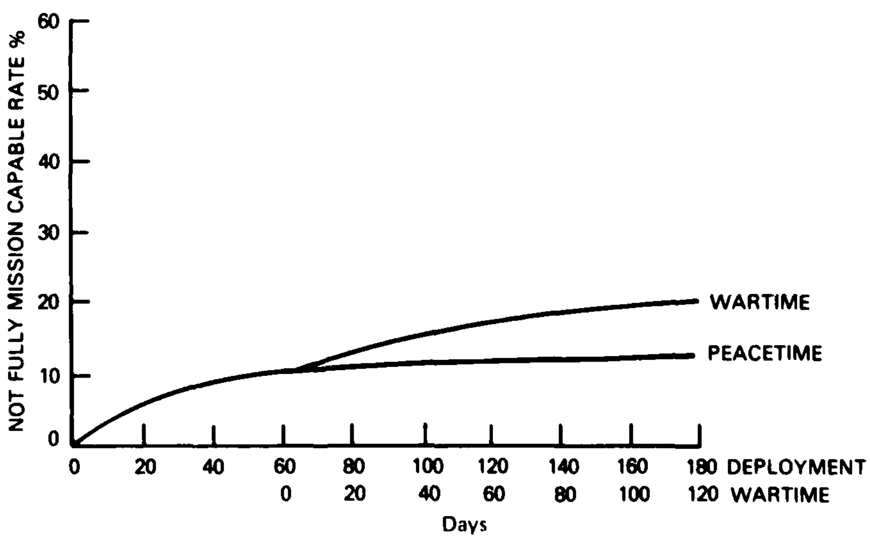
[3] We recently learned that the Navy has not been allowed to buy the OST safety level despite the inclusion of it in their requirements calculations. To the extent this stock is not provided, we have overstated the serviceable spares. Generally, this will be a small amount, and since we buy the same dollar amount of stock for all structures, this should not affect the analysis.

of our assumption of "full up" serviceable stock at the time of deployment. If the initial stock level is degraded to something less than full authorized levels and some stock is in the repair pipeline, then the results would be essentially the same but would be shown with time of deployment moved to the right. In this first case we have not allowed the SRA AWP time or the B&P AWP to affect the WRA repair times. This would be the situation with unlimited SRAs and B&P. Note that this 10 percent NMCS rate occurs at peacetime flying rates despite the fact that spare stock is provided for projected wartime flying rates, reflecting (if it is judged that 10 percent NMCS is high in peacetime) the fact that inadequate protection is provided by WRA spares.

The second curve, labeled WARTIME, indicates the growth in NMCS when the flying program shifts to projected wartime flying rates at day 60 after deployment. Despite unlimited piece parts and SRAs, the wartime NMCS grows to 15 percent by day 30 after the shift and to nearly 20 percent by day 120, again reflecting shortfalls in WRA spares.

Figure E-3 indicates the effect of shortages in SRA and B&P spares under projected wartime flying conditions. The lower curve shows the time-dependent performance when SRA AWP time is allowed to affect the shipboard repair time of WRAs. Depot repair is assumed to be unaffected by AWP time. We found the AWP time due to SRAs reaching 3.6 days by the 120th day of wartime flying rates despite initially providing full authorized stock for the SRAs for the projected wartime flying rate. Recall also that because of certain modeling assumptions it was necessary to eliminate

Figure E-2. Current structure performance with continuous resupply from ashore no AWP.

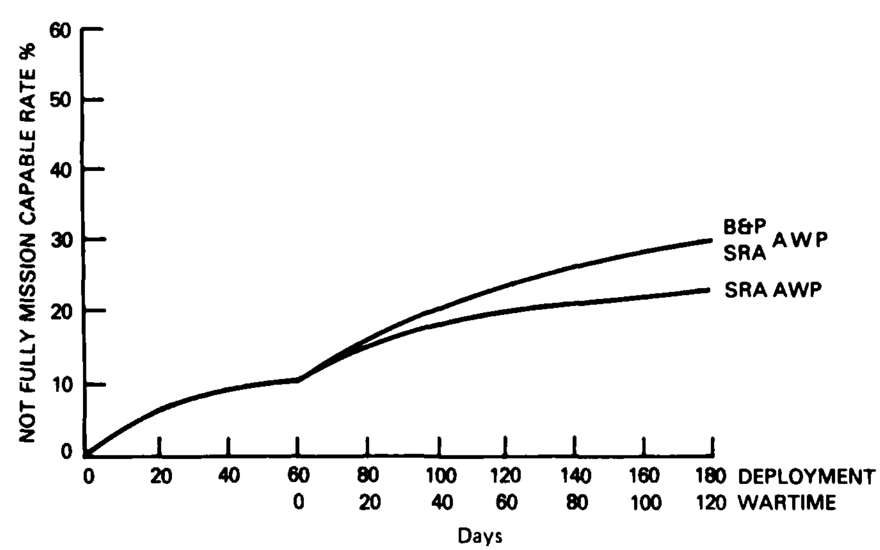


some of the SRAs from consideration. With their inclusion and a deployment with less than full authorized SRA stock, the AWP time would probably be higher, as demonstrated by current average AWP times of five to seven days experienced under peacetime flying conditions.

The top curve in Fig. E-3 illustrates the potential effect of B&P AWP as it ripples through to create higher SRA shortages and ultimately a higher NMCS rate. In stocking the piece parts we provided a safety factor of 0.9, so that stock was provided at a level equal to the integer part of 90 days of projected wartime demand plus 0.9. That is, if the B&P demand for 90 days was at least 0.1, then the item was stocked. Thus somewhat more protection was provided for bits and pieces than for SRAs and WRAs, which required a demand of about 0.9 before an item was stocked according to the fill rate calculations. Again, depot repair was assumed to be unaffected by bit-and-piece shortages. When the B&P effect is considered for shipboard repair, we see an NMCS rate that reaches almost 30 percent by day 120 of simulated wartime activity. Clearly, *the dependency of shipboard repair on SRAs for WRA repair and on B&P for SRA repair diminishes the self-sufficiency of the squadron, if those components are not stocked at a high level with respect to that single squadron's activity.*

So far we have shown operational performance using the repair cycle times given in the ASO S-3A data tape. Current maintenance experience, as reflected in 3M data and by discussions with ASO personnel, indicate that these data understate the current actual repair times. This experience indicates that times on the average of 9.5 days, without AWP included, are more likely than the five to six days shown in the

Figure E-3. Current structure performance with continuous resupply from ashore with AWP.

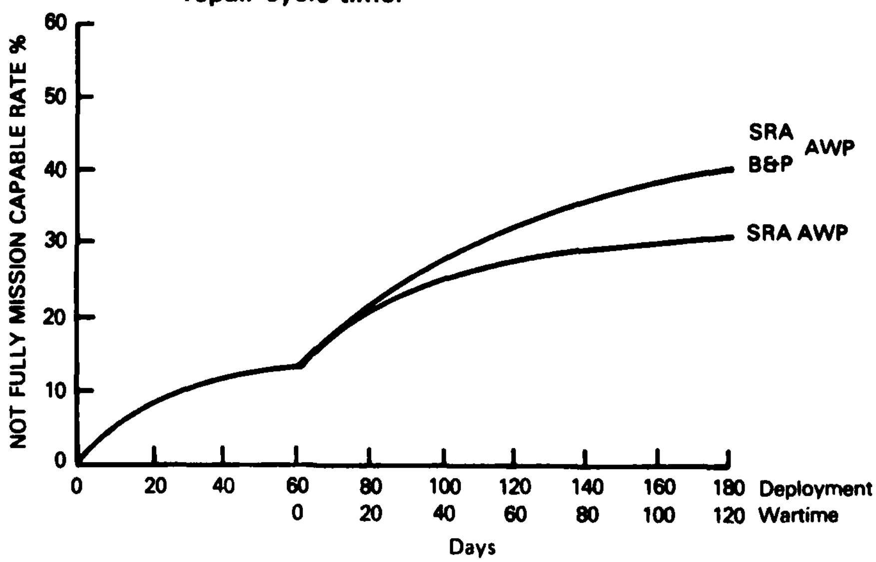


ASO data. To create the curves in Fig. E-4, we adjusted all repair times in the data upward by a constant factor to achieve an average time of 9.5 days for shipboard repair. The effect of this has been to degrade the performance of the S-3A squadron by an additional 10 percent, so that by day 90 of wartime activity the NMCS rate is nearly 40 percent. Clearly, *the Navy's expressed goal of 90 days of self-protection at wartime activity rates is not likely to be met, or must be expressed in terms of degraded capability shortly after the start of that 90 days.*

This last case, which considers the effect of B&P and SRA AWP time and which considers the current experience with longer repair times, is used as the base case for comparison with the alternative structures presented in the next sections.

So far we have assumed that the transition to wartime activity rates occurred with no interruption of pipelines. In Fig. E-5 we have superimposed the effect of cutoff of depot resupply (due, say, to the high rate of use of air transport for other activity) on the base case curves of Fig. E-4. Here it is seen that when one considers either AWP due to SRA limitations only, or AWP that also includes B&P effects the NMCS rate rises rapidly after the start of wartime activity. In the latter case a 30 percent NMCS rate is reached by the 30th day into wartime activity and a *50 percent* NMCS rate is reached by the 60th day. *In this cutoff case, where self-protection is most important, it is clear that due to the small scale of operation both the range and depth of B&P stock and SRA stock inhibit the self-sufficiency of carrier operation that is supposedly obtained with shipboard intermediate level repair.* Within a few days after cutoff, shortages in B&P stock appear and affect the repair time of SRAs. This in turn

Figure E-4. Current structure performance with continuous resupply from ashore with AWP and with increased repair cycle time.

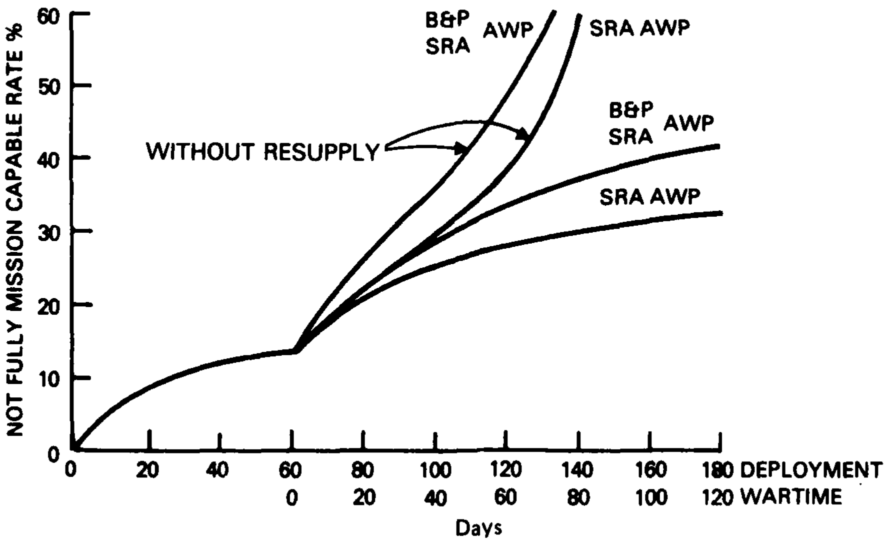


causes shortages of SRA components as they sit in the repair pipeline in AWP condition. These shortages affect the repair time of the WRAs, draw down the WRA spares, and ultimately holes in aircraft appear, leading to loss of capability and NMCS conditions. The following sections will examine some alternatives that attempt to improve the period of self-sufficiency by (1) improving shipboard repair times by reducing the scope of that repair, (2) increasing the amount of WRA stock for those components not repaired on the ship, and (3) improving the shore-based support to maintain a higher state of readiness as protection against cutoff.

ALTERNATIVE STRUCTURE: MOVING REPAIR FROM SHIP TO SHORE

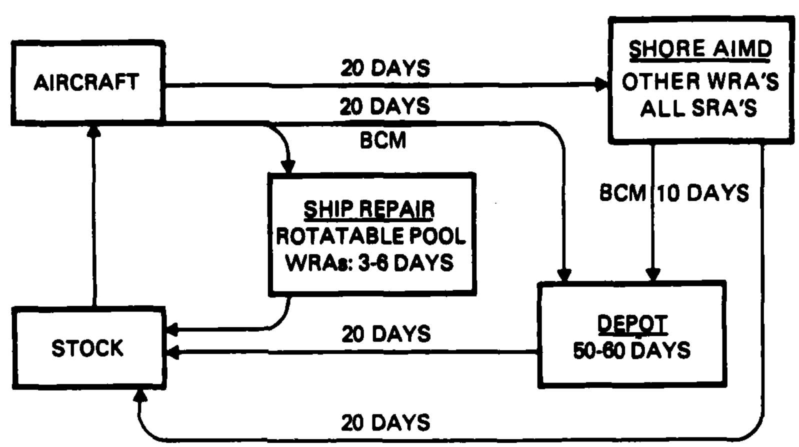
Numerous reasons for moving repair off the ship have been suggested in the main body of this report. They center primarily on issues of scale. As a starting point, in order to understand the performance implications of such a move, it has been assumed that under this alternative only the repair of rotatable pool WRAs would remain on the ship. All repair of non-rotatable pool WRAs and all SRAs would be accomplished by a shore-based AIMD. As we have said, this is seen only as a starting point. If the Navy finds this alternative attractive, a complete level of repair analysis (LORA) will have to be accomplished, the results of which might indicate a different mix of components whose repair would remain onboard. However, given that the rotatable pool WRAs are typically the high-fail, expensive, mission-critical components,

Figure E-5. Current structure performance without resupply from ashore compared to continuous supply.



it was felt that leaving their repair onboard was a reasonable place to start. The alternative structure is show in Fig. E-6.

Figure E-6—Alternative structure pipeline: shore repair



Reduction in Repair Cycle Time

This alternative is expected to reduce the repair cycle times onboard ship from the current average of 9.5 days. The primary reason is that the onboard workload would be reduced 30 to 40 percent. In terms of the number of line items, only the repair of 64 rotatable pool WRAs would remain out of an approximate total of 700 WRAs and SRAs that are currently shipboard reparable.

As a result, test equipment queuing should obviously be reduced. For example, the VAST is currently required for test and/or repair of about 163 S-3A components (64 WRAs and 99 SRAs). Under the alternative, only 48 rotatable pool WRAs would remain to be repaired on the VAST — a reduction of about 70 percent in the number of line items requiring the VAST.[4] In addition, there would be no SRA-WRA conflicts for the use of test equipment and less time spent in setup.

The number of items (SRAs and B&P) required onboard to support repair under this alternative has been drastically reduced to include only those SRAs required to repair rotatable pool WRAs. Under these circumstances we would suggest that these items be made more accessible to the location where the repair is taking place, thus

[4] Unfortunately, workload data were not readily available, so we do not know at this time what reduction in VAST throughput is likely to occur.

reducing the repair time of the WRA by reducing the time spent in obtaining the necessary repair part.

The shore-based AIMD facilities would have to be scaled up to meet the increased workload. It was assumed here that the shore-based facilities would be provided sufficient resources so that, along with the opportunities to batch process and the increased effectiveness of the larger-scale operation, they too would enjoy a significant reduction in repair cycle times.

For study purposes, we assumed that a goal of an average of three days repair cycle time for WRAs is not unreasonable. It case this was regarded as too optimistic, cases with about a six-day average were also run. These latter times were the same times that were in the original data provided by ASO.

Impact on AWP

With all of demands for the low-demand items consolidated at one point on each coast (six carriers plus shore-based), we would expect a significant reduction in AWP. We would expect the range of items stocked at the shore-based facility to increase because of sufficient demand to warrant a higher-than-zero stock level. We would also expect that the shore-based facility would be free of the stowage constraints that occur on the ship. These assertions apply in particular to the bit and piece part problem discussed above. Therefore, the AWP "ripple" effect should be minimized. On the ship, only high-demand SRAs required to repair rotatable pool WRAs would be stocked. In addition, because of the reduced AWP there should be less adverse AWP impact on WRA repair cycle times.

Other Possible Benefits

This alternative is likely to yield a number of additional benefits. The larger-scale operation should provide increased availability of higher skill levels, operate more like a production facility, and furnish the opportunity for a more rigorous quality control program. This should result in improved quality of component repair (increased MTBF), less reliance on depot repair (lower BCM rates), and more opportunity for priority production scheduling to compensate for shortages of particular components.

In addition, the increased scale may reduce the requirement for test equipment, especially equipment that currently experiences low utilization rates on board the ship. Fewer sets of such equipment may also be required at the shore-based facility. Moving test equipment off the ship has the additional advantage of not requiring repair or spare parts for that test equipment on the ship.

Of these potential added benefits, only the reduction in BCM rates will be considered in this analysis. It will be addressed specifically in the section below entitled, "Move Depot Repair to Shore-Based AIMD."

Transportation Assumptions

Under this alternative it is obvious that additional transportation capability will be required because more components are moving on and off the ship. Although no specific data concerning weight and cube requirements were available for this analysis, we estimate that the number of WRAs and SRAs moving on and off the ship would approximately double. For purposes of analysis, it is assumed that the required transportation is available and that the transit times (ship to shore) are the same as they are in the current structure (20 days). An additional 10 days transportation time has been added for those items that must first go to the shore facility and then on to the depot for repair. (See Fig. E-6).

Stockage Assumptions

In computing the stock requirements for the alternative structure it was assumed that an equal amount of money can be spent so that we have an equal stockage cost comparison. To accomplish this, *all* pipelines in the alternative (Fig. E-6) were stocked at the 90 percent Poisson level of protection. Then a constant factor was applied to the computed level for each item such that the total cost of all items was approximately equal to the total cost of all items computed for the current structure. The cost of bits and pieces was not included in either case, as no data were available.

The result is a change in the mix of items.[5] With the reduced repair cycle times, fewer rotatable pools WRAs are required. These tend to be the expensive, high-demand items. With the increase in pipeline times for non-rotatable pool WRAs and all SRAs, more of these items were stocked. With the consolidation of demand for bits and pieces at one location (the shore-based facility), it was assumed for analysis purposes[6] that an infinite number were available. As before, it was assumed that all stock was on the ship at the day of deployment and that the pipelines were empty.

Analytical Results

As was indicated earlier, two assumptions about WRA repair cycle time improvements were made. Figure E-7 shows the results for a 3-day average and Fig. E-8 shows the results for an average of about 6 days (those times being found in the original ASO data). The comparisons are made against the base case developed in the preceding section under wartime conditions, with the war starting on day 60 of a peacetime deployment.

Note in the figures that under conditions in which resupply from shore continues uninterrupted, the shore repair alternative does significantly better. By day 120 of the war the current structure can expect a not-fully-mission-capable rate of about 40 percent. For a WRA repair cycle time of three days (Fig. E-7) it is about 25 percent by day 120. For six days it is about 30 percent.

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[5] It can be argued that for a well-established weapon system this ability to buy an alternative mix of stock is limited since most of the stock is already purchased. In such a case, either there would have to be a gradual shift to the new mix as replacement components are ordered, or additional monies would have to be spent. In newer weapon systems with incomplete or understated initial provisioning, this conversion would be easier. The amount of money that was reallocated in the new mix for these alternative structures amounted to about 20 percent of the total dollar amount.

[6] As this is an illustrative analysis with one ship, one shore facility, and one depot, this is a reasonable assumption to make in order to demonstrate the improvements in bit-and-piece AWP likely to occur under this alternative. Future analyses should deal with the bit-and-piece problem explicitly for both the current and alternative structures and for the support of six ships rather than just one.

Figure E-7—Current and alternative structures with and without resupply from ashore—repair cycle time: 3 days.

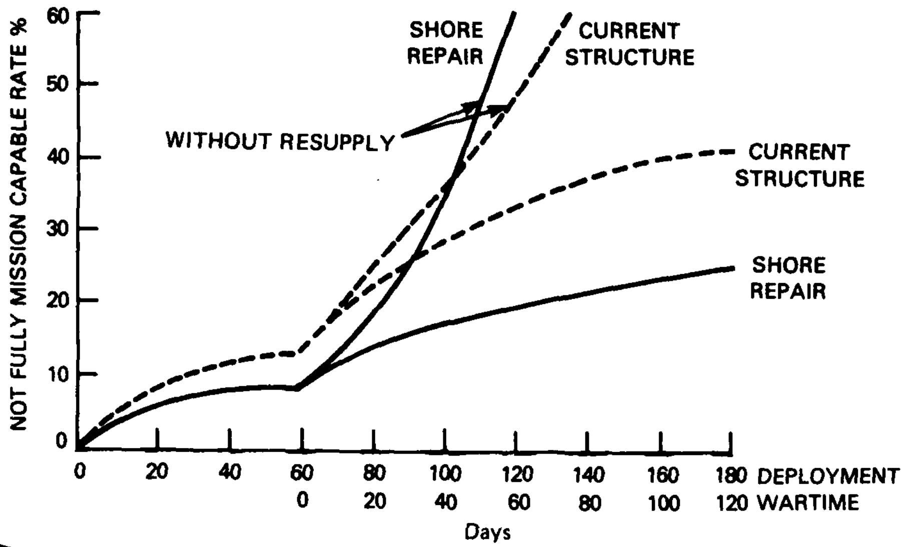
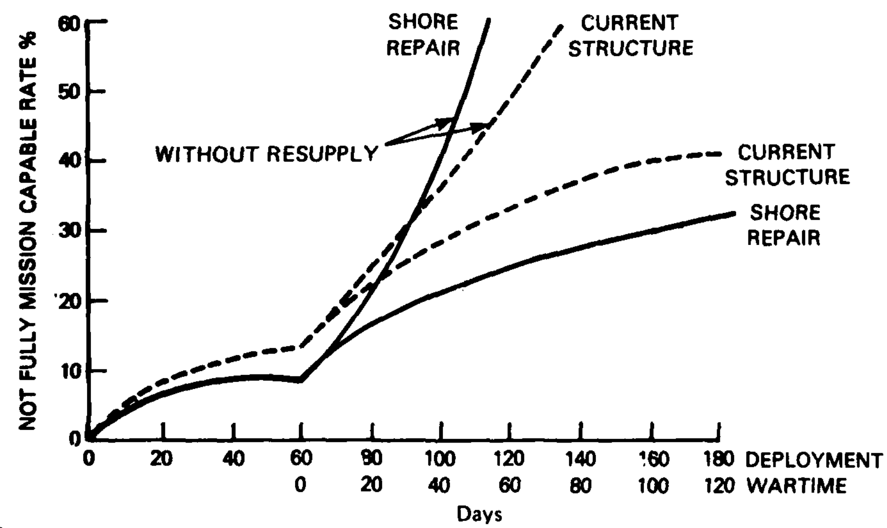


Figure E-8. Current and alternative structures with and without resupply from ashore—repair cycle time: ≃ 6 days.



The shore repair alternative obviously places an increased reliance on transportation. Therefore, under conditions where shore resupply is cut off at the beginning of the war the rate at which the not fully mission capable rate increases should be greater under the alternative. Note, however, that because the shore repair alternative places the ship in a better position at the start of the conflict, the curves do not cross until about day 45 of the conflict in the case of the 3-day RCT assumption or until day 30 for the six-day RCT assumption. This means that for some substantial period of time the alternative structure performs better. Furthermore, it is only a short time later when the current structure also incurs a substantial NMCS level.

It appears then, given the limited analysis performed thus far, that the shore repair option shows promise of outperforming the current structure under conditions of continuing resupply and for some period of time when resupply is cut off. The next section will address the case where BCM rates are improved by moving repair from the depot to the shore-based AIMD.

ALTERNATIVE STRUCTURE: MOVE DEPOT REPAIR TO SHORE-BASED AIMD

The previous section discussed the possibility of reduced BCM rates resulting from the increased scale of the shore-based operation. This would be an important outcome, because reductions in the long depot repair pipelines (approximately 100 days) would make more stock available to the system.

Pipeline reductions appear to be possible independently of the shore-based repair alternative. Discussions were held with a number of maintenance personnel with regard to this long pipeline. Many of them contended that much of the work sent to the depot could be accomplished at a shore-based AIMD with existing skills and test equipment. Their estimates ranged from 50 to 80 percent reduction in BCM if that work were moved to the AIMD.

For purposes of analysis it was assumed that a 50 percent reduction in BCM rates for all items was possible. Clearly, the amount of reduction would vary across items, but since no specific data were available, this assumption seemed reasonable for illustrative purposes. This alternative structure is shown in Fig. E-9.

All other assumptions are the same as those presented in the previous section. Stockage was also computed in the same manner, except that it was based on the different pipeline times that result from the reduced BCM. The analysis, as before, is an equal stockage cost comparison.

The results are shown in Figs. E-10 and E-11 for the 3-day and 6-day WRA RCTs, respectively. Note that under the condition of continuous shore resupply, the expected not-fully-mission-capable rate has dropped to 20 percent for the 3-day RCT case and to 27 percent for the 6-day RCT case at day 120 into the war.

In the case where shore resupply has been cut off, the crossover of the two alternatives occurs at about day 50 of the war for the 3-day RCT case and at about day 35 for the 6-day RCT case. Again we see improved performance of the alternative. Having less stock tied up in the long depot pipelines obviously will improve performance.

Figure E-9. Shore repair alternative with improved BCM.

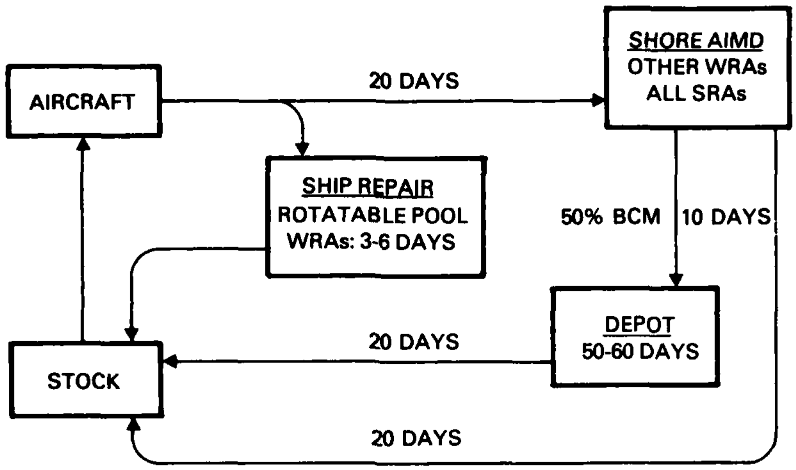


Figure E-10. Current structure and shore repair with improved BCM with and without resupply from ashore— repair cycle time: 3 days.

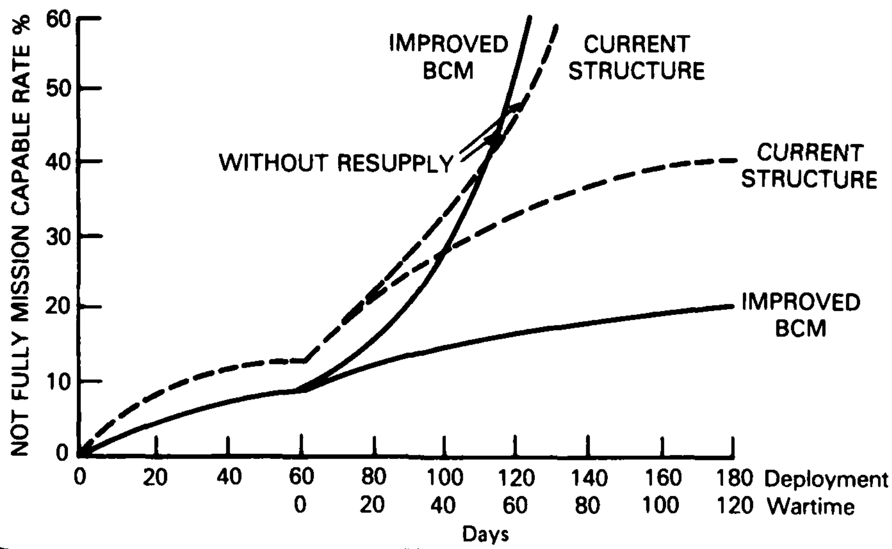
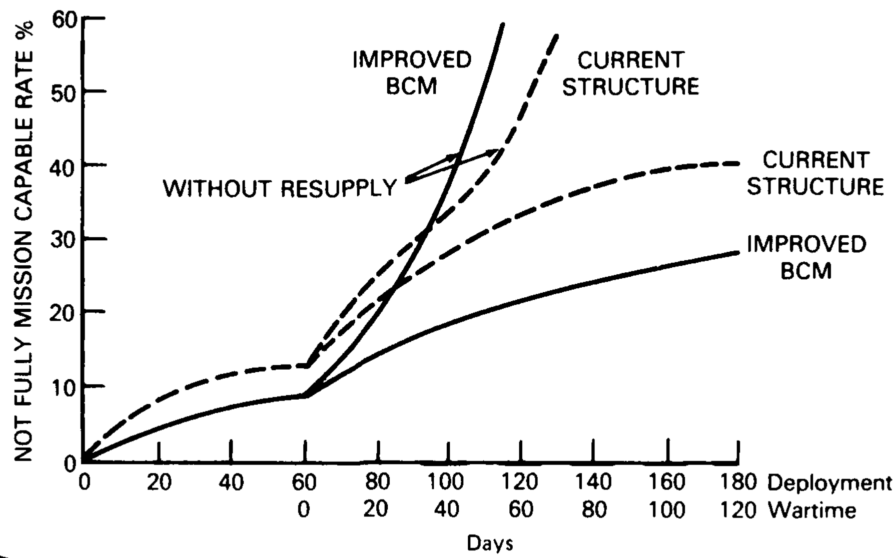


Figure E-11. Current structure and shore repair with improved BCM with and without resupply from ashore— repair cycle time: ≅ 6 days.



LOGISTICS SUPPORT ALTERNATIVES FOR THE B-52/ KC-135 WEAPON SYSTEMS

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SUMMARY

This case study compares the current support structure for the SAC B-52/KC-135 fleet with a structure developed at RAND in the early 1970s called the Reallocation of Activities Alternative (RAA). With an RAA support structure, most activities are consolidated at a Support Mission Base (SMB) which supports very limited activity at its associated Combat Mission Bases (CMBs). For this application, essentially all activities for a given Mission Design Series (MDS) are assigned to one SMB, with CMBs providing dispersed sites for standing alert and maintaining survivability of the fleet. In this study, a hypothetical beddown is constructed for comparison with the current structure consisting of 84 B-52Hs, 139 B-52Gs, and 435 KC-135s assigned to 24 Main Operating Bases (MOBs). The comparable RAA structure, which uses the same number of bases, has one SMB each for the B-52G and H, two SMBs for the KC-135, six CMBs for B-52G alert, four CMBs for B-52H alert, and six CMBs for KC-135 alert with KC-135s also standing alert at each of the bomber SMBs and CMBs. (Four MOB's remain in the RAA structure to support the B-52D and the FB-111.) This study compares the costs and effectiveness of the two structures.

The study was motivated by the decision to use the B-52 as the carrier for the Air Launched Cruise Missile (ALCM). With this decision, the life of the B-52 in the Air Force inventory has extended into the foreseeable future. Since one of the main advantages in the RAA is a reduction in the recurring costs of operation, the extended life of the B-52 makes the RAA a more attractive option. Additional benefits in terms of reduced procurement should also be gained for the ALCM, with support equipment and personnel required at far fewer locations. The increase in scale at the SMBs should also allow some depot-level work on the ALCM to be performed at base level. This may provide substantial cost avoidance in equipment, people, and spares acquisition for the ALCM.

The results of this analysis indicate that the RAA (as the support structure for the B-52G, B-52H, and KC-135) would save about 18,000 people. Over 60 percent of that saving would come from base support services, and about 30 percent from economies of scale in the primary mission elements. This reduction equates to a savings of $250 million a year. The RAA also requires fewer spares to support the weapon systems, amounting to a reduction of $32 million in spares required, yet maintaining the aircraft at a higher OR rate than the current structure. These excess spares could be used to reduce out-year replenishment spares buys.

A number of RAA's aspects require a detailed bed-down before it can be compared with the current structure. Some attempt has been made to estimate additional facilities cost; the rough estimate indicates that RAA could require $150 million for additional facilities on the SMBs, a cost that would be more than paid off by one year of manpower savings. The actual cost could be less, if bases other than the ones owned by SAC were available. A more detailed analysis of facilities requirements of an actual bed-down is still required. No attempt has been made to quantify costs of a transportation system to support the RAA, although this cost is not expected to be a driving factor. Finally, although Rand performed studies of force survivability under

the RAA and found it essentially the same as under the current structure, an updated analysis is needed in light of current Soviet capabilities, new alert rates, and changes to available SAC bases.

The areas addressed in this study indicate that the RAA has several striking economic advantages over the current structure; the scale of these economies warrants further detailed implementation analysis by the Air Force.

I. INTRODUCTION

BASIC CONCEPTS OF THE STUDY

The case study of Logistics Support Alternatives for the B-52 investigates whether organizational and procedural changes can reduce the operating and support costs that would be required under *current* logistics concepts for the projected ALCM force, while maintaining mission capability. The CONUS-based KC-135s are also considered. The analysis is based on the following concepts:

- Consolidating ALCM carriers and missiles on as few bases as possible, given survivability and other mission constraints.
- Centralizing maintenance and support operations at these larger bases.
- Providing decentralized, smaller, operating bases with sufficient support capacity to provide survivable combat-ready strategic capability.
- Migration of SAC repair workload from the depot system to SAC.

The Air Force has recently considered various forms of these concepts. Their integration into a support concept is the subject of this preliminary analysis by the DRMS. It is our understanding that CINCSAC believes that a thorough evaluation of these concepts for the Air Launched Cruise Missile (ALCM) carrier is warranted.

BACKGROUND

With the President's decision to cancel production of the B-1, the DoD will have to rely on the B-52 as the backbone of the aircraft portion of the strategic triad for a number of years. The Air Force plans to maintain 20 B-52 strategic bomber squadrons in the inventory. The introduction of the ALCM and the decision to utilize B-52Gs and Hs as ALCM launch vehicles, offers a new opportunity to reexamine the logistics support policies for the B-52.

The current logistics support policies were originally based on the requirements of the massive retaliation role. Strategies have altered over the years, and there has been a considerable reduction in the number of aircraft assigned to the strategic role. The support posture, however, has remained essentially the same. Maintenance is conducted at bases designed to have a high degree of self-sufficiency. Each base performs on-aircraft work (organizational maintenance) and component repair (intermediate maintenance) in specialist repair shops. Depot level maintenance on both aircraft and aircraft components is the responsibility of the AFLC. The supply system to support the B-52 is a two-echelon system with supplies stocked at each base and at wholesale supply depots. The base orders supplies directly from the wholesale source, which is the AFLC for most weapon-system-peculiar parts and the DLA for most common items.

The three-echelon maintenance system (organizational, intermediate, and depot) and two-echelon supply system (base and depot) are standard Air Force systems and have served SAC well. However, over the years the costs of support have risen, basic strategies have changed, and the B-52 fleet has diminished in size. The advent of the ALCM, with added support requirements for manpower, facilities, test equipment, spare parts, and handling equipment provides an opportunity to consider an alternative support structure that can reduce both operating costs and acquisition costs for support equipment and facilities while enhancing mission capability. This structure was developed at The Rand Corporation in the early seventies and was called the Reallocation of Activities Alternative (RAA).

THE ALTERNATIVE SUPPORT STRUCTURE (RAA)

The essence of the RAA concept is the reallocation of support activities to a limited number of bases (Support Mission Bases — SMBs) while retaining other bases as alert dispersal sites (Combat Mission Bases — CMBs) to maintain the required level of survivability. Currently, B-52 wings operate out of Main Operating Bases (MOBs) that are essentially identical, with a full range of organizational and intermediate maintenance, supply, personnel, medical, and transportation support. In contrast, RAA bases vary according to their specific missions and activities. The SMB is a very large base (two to four times as large as current MOBs) that supports a particular type of aircraft, with maintenance, proficiency training, and base operating support for all aircraft on the base plus all aircraft on its CMBs. The CMBs are small, limited activity bases that depend on their SMB for most of their support. They are sized to permit launch and recovery of aircraft with limited organizational maintenance, munitions, and POL. It is assumed that weapon storage areas (WSAs) would be maintained at each SMB and SMB. The crews and aircraft at a CMB have the SMB as their home base. The CMB's major task is to receive incoming alert aircraft, maintain them while on alert, and launch them for their return to the SMB or for their combat mission. CMBs are more than satellites, however; they are larger, less destructible, and more self-sufficient. They are more akin to a SAC concept of the early 1970's called Auxiliary Alert Sites.

Figure 1 depicts six bases under the current structure, and Fig. 2 the same six bases under the RAA. This hypothetical situation is meant to illustrate the proposed reallocation of activities, given a fixed number of bases.

By maintaining the same number of alert aircraft at the same number of sites, the RAA theoretically leaves the vulnerability of the system with respect to alert aircraft essentially unchanged. The original Rand study analyzed relative vulnerability in some detail. The DRMS has not done that for this alternative. This is one of the key characteristics that must be evaluated under specific threat, bed-down, and alert assumptions. The increased scale of the SMBs, however, provides for some mission-enhancing economies while the reduced scale of the CMBs markedly decreases the total cost of operation.

Figure 1. Current structure.

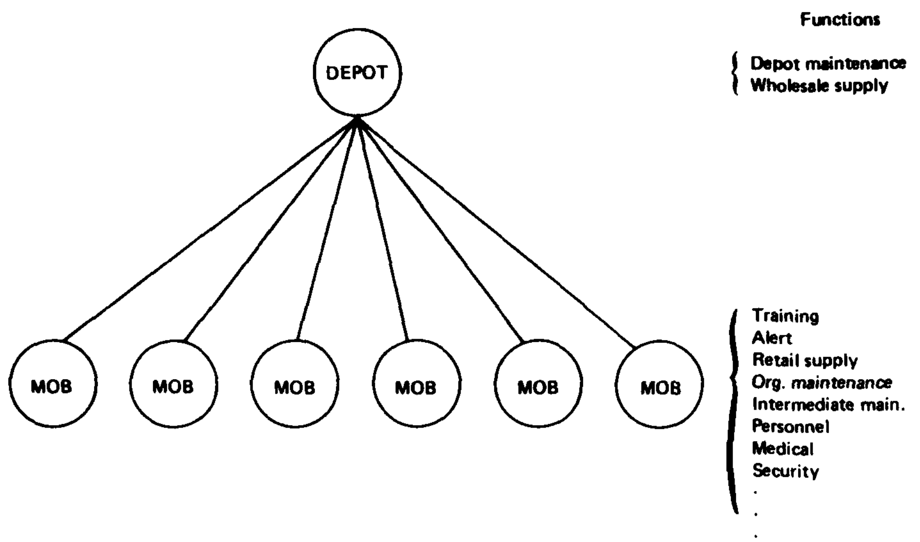
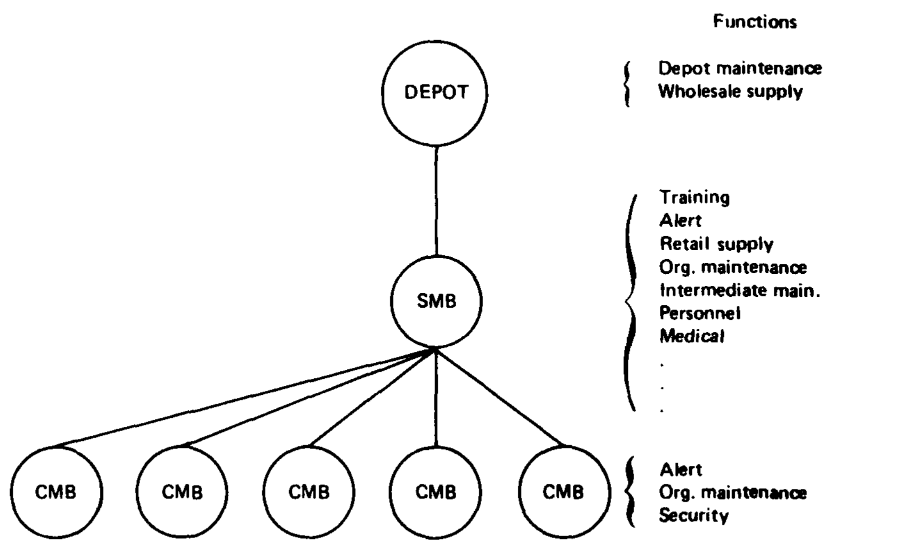


Figure 2. The RAA.



IMPACT OF THE ALCM

The original Rand studies of the RAA showed a significant reduction in recurring costs, particularly manpower costs, over the current structure. At that time, however, the B-1 was expected to replace the B-52 in its bomber penetration mission, and the B-52 was expected to be phased out of the inventory in the near future. The RAA did and does require some capital investments to scale up current MOBs to SMBs. With the time required for transition to the new B-1 structure, and the limited life remaining for the B-52 to recoup the initial outlays with recurring savings, there was little motivation to adopt the suggested alternative. In addition, the penetration mission was extremely complex, requiring extensive crew training to maintain proficiency. There was therefore some question whether adequate crew training could be provided without significant ground training while on alert at the CMBs.

The advent of the ALCM has extended the service life of the B-52 into the foreseeable future. This enhances the attractiveness of the RAA in several ways. First, the recurring cost savings of the RAA become much more significant with a possible 20-year future for the B-52. Secondly, the B-52 is an aging weapon system and the maintenance required to keep it serviceable will tend to increase. Consolidation of all maintenance at an SMB provides an increased scale that will make it easier to match personnel and spares to the maintenance requirements. Finally, the cost of military manpower continues to rise, creating pressure to reduce manpower requirements. The RAA could provide a way to reduce B-52 military manpower requirements significantly while maintaining the effectiveness of the force.

The ALCM will also reduce the complexity of the B-52 penetration mission. This can be expected to reduce crew training requirements, perhaps to the point where no training is needed while on alert at the CMB. Even if some ground crew training is required at the CMB, consideration of the RAA structure during development of the ALCM may allow techniques, such as mobile trainers, to be developed that will not require creation of a fixed training facility at the CMBs.

Because the ALCM is still in an early developmental stage, we cannot accurately predict how its support requirements would differ under the current structure and the RAA. This stage offers the opportunity, however, for the RAA to influence ALCM development so that minimal resources are required at the CMBs. Fewer maintenance shops will have to be equipped and staffed (two SMBs in the RAA versus 12 MOBs in the current structure). Considerably less depot repair will be required for the ALCM since, with only two repair points, the Optimal Repair Level Analysis (ORLA) model will drive some depot repair items to be repaired at the SMBs. Finally, the requirements for spare parts will also be reduced considerably by consolidation at two locations.

This case study provides an initial comparison of the projected costs and benefits of the RAA and the current structure in support of the ALCM fleet. It relies heavily on the Rand analyses of the RAA conducted in 1973 and 1974. Since those analyses were performed, the B-52 fleet has changed considerably in basing, alert rates, numbers of UE, and crew ratios. These factors are integrated into the current analysis and significantly change some of the quantifiable results. The basic conclusions of the original studies still stand however; the RAA offers an alternative support structure that maintains the effectiveness of the force at a considerably reduced operating cost.

II. COMPARISON OF THE RAA AND THE CURRENT STRUCTURE

The comparison of the two structures is based on a representative bed-down of the B-52/KC-135 fleet as it might look upon introduction of the ALCM. The RAA alternative is constructed to provide the same number of alert sites as the current structure to minimize the effect on force survivability. Since the RAA is geared to supporting the relatively inexpensive CMBs from an SMB, force survivability could be readily enhanced under the RAA by the addition of more CMBs. It simplifies this initial analysis, however, to keep survivability essentially the same under both structures. Survivability of the two structures will be discussed in more detail in a later section.

This study also compares manpower requirements, reparable spares requirements, facilities, and quality of life issues. The Rand study of the RAA provides the framework for the comparisons. Where necessary, those results have been adjusted to reflect the changes in the strategic force in its peacetime operational scenario since 1974. A concluding section discusses remaining areas of analysis and some of the problems of implementation.

SCENARIO FOR THE COMPARISON

There have been a number of changes in the nature of the B-52 force since the original RAA analyses. Although the analytic approach used is still valid and will be followed in this case study, a new scenario was constructed for the comparison that reflects the currently envisioned operational environment. The relevant factors required for this comparison are: number of UE, alert rates, crew ratios, activity rates, and basing of the B-52/KC-135 fleet. Table 1 provides the values for the first four factors, while Table 2 displays the assumed basing for this analysis.

The B-52G and B-52H are to be the prime carriers for the ALCM. The B-52D, although included in the original Rand analysis, is therefore not included here except as it affects the basing costs of the colocated KC-135s. The RAA structure for this analysis will have four SMBs, one each for the B-52G and B-52H, and two for the KC-135. Since the B-52G is currently located on seven bases, there will be six B-52G CMBs in the RAA. Similarly, the B-52H will have four CMBs. The KC-135 fleet will stand colocated alert at each of the bomber CMBs and SMBs, at each of the three B-52D MOBs, and at one FB-111 MOB. To maintain the same number of alert sites as the current structure, the KC-135 will require six additional CMBs. Figure 3 depicts basing for the three aircraft types under the RAA. The number inside each circle is the expected number of aircraft (excluding alert) on that base; the paired numbers under the circles are the numbers of bombers/tankers on alert at that site. (At the remaining MOBs the numbers inside the circles refer only to the numbers of tankers there.) The alert rates correspond to those in Table 1. If the alert rate were increased to, say, 40 percent, the number of aircraft on the SMBs would be reduced by 14 percent. The CMBs would then be sized to accept a 33 percent increase in alert aircraft. Note that the SMBs themselves have a significantly smaller alert force than

Table 1.—SAC bomber/tanker operating parameters for this analysis

Parameter	B-52G	B-52H	KC-135
Alert rate (percent)	28.0	28.0	30.0
Crew ratio (crews/acft)	1.3	1.3	1.27
Activity rate (sorties/crew/mo)	3.0	3.0	3.0
No. of UE (CONUS-based) [1]	139.0	84.0	435.0

[1] As in the original Rand analysis, those aircraft assigned to the CCTS at Castle are not included in this analysis.

the CMBs. This is because the SMBs are envisioned as being located in desirable areas to improve the "quality of life" of SAC personnel. Since desirable areas tend to be in areas of short strategic warning, the dominant portion of the alert force is placed on the CMBs, which are situated at locations with maximum strategic warning. Because of the large number of KC-135s in the force, not all of them are to be maintained at two SMBs; 30-UE wings are stationed at the B-52D MOBs, the FB-111 MOBs, and the B-52H SMB. The manpower computations that follow are based on this scenario. If the size of the SMBs had to be further reduced, additional aircraft squadrons could be bedded down at the four tenant bases, which become CMBs under the RAA structure. This would increase the RAA manning by about 500 people, less than three percent of the total manpower savings of the RAA.

The comparative analysis of the two structures is based on the current structure represented by Table 2 and the RAA structure as depicted in Fig. 3. The B-52D and FB-111 are not considered in this comparison. However, as suggested in the original Rand study, the RAA structure could be considered for extension to these MDS as well.

COMPARISON OF MANPOWER COSTS

This analysis builds on the initial Rand analysis of the RAA, which used a model of bomber/tanker operating costs developed at Rand.[1] Results from the model indi-

[1] The model is documented in R. W. Hess, *BOMTAN: A Model for Estimating the Annual Cost of Bomber and Tanker Squadrons*, R-1438-PR, May 1974 (FOUO), and R. W. Hess, *BOMTAN: A Model for Estimating the Annual Cost of Bomber and Tanker Squadrons: A Classified Supplement of Estimating Relationships and Cost Factors* (U), R-1439-PR, May 1974 (Secret).

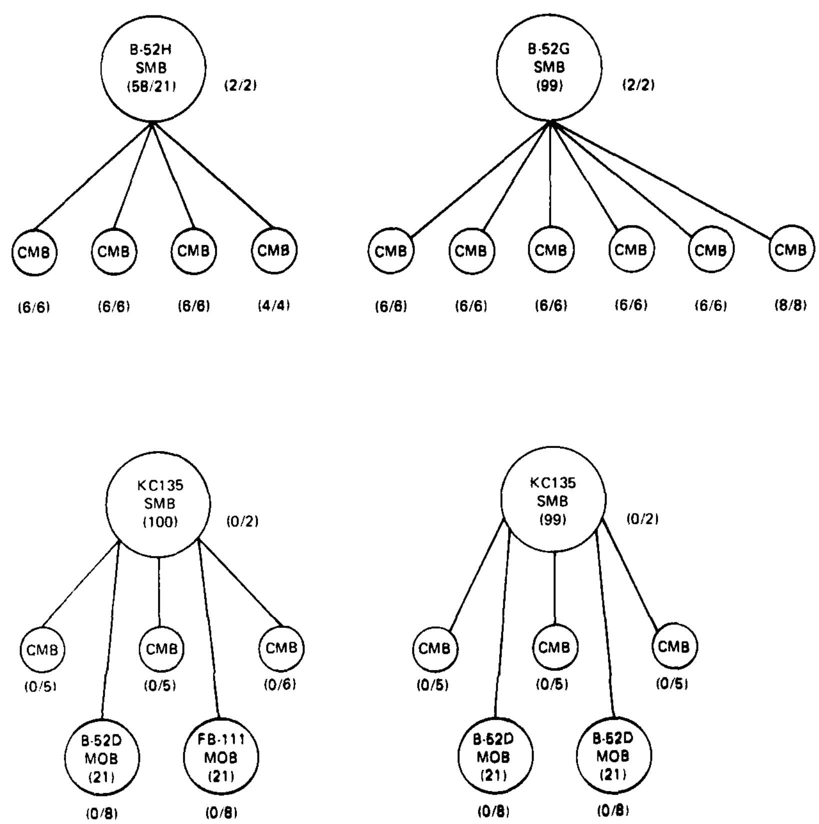
Table 2.—Assumed basing structure

Base No.	Number of UE at each base B-52G	B-52H	KC-135
1	16	0	13
2	16	0	16
3	16	0	19
4	30	0	9
5	16	0	30
6	15	0	14
7	30	0	18
8	0	20	19
9	0	18	19
10 [1]	0	15	13
11	0	16	13
12 [1]	0	15	14
13 [1]	0	0	19
14	0	0	30
15	0	0	14 [2]
16	0	0	24
17	0	0	30
18	0	0	13 [2]
19	0	0	18
20	0	0	12 [3]
21	0	0	30
22	0	0	15
23 [1]	0	0	14 [2]
24 [1]	0	0	19
Totals	139	84	435

[1] Non-SAC (Tenant) bases.
[2] Colocated with B-52D wing.
[3] Colocated with FB-111 wing.

cated that the RAA could save manpower in two areas. The first is base level support (Base Operating Support (BOS), and Personnel Support (PS)). A typical MOB provides a wide range of services to its inhabitants. Each of the functions provided requires an initial increment (Base Opening Package (BOP)) of personnel independent

Figure 3. RAA basing structure.



of operational units on the base. A typical SAC BOP is shown in Table 3. As operational units are brought onto the base, additional BOS and PS personnel are required to handle the variable workload.

Table 3.—Base opening requirements for a MOB [1]

Item	Officers	Airmen	Total military	Civilian	Total
SAC base opening package	45	760	805	349	1154
Personnel support	2	54	56	2	58
	47	814	861	351	1212

[1] USAF Cost and Planning Factors Manual (U), AFM 173-10, (Confidential).

This manpower is required at every MOB to provide the required services. Scaling an MOB down to a CMB, which requires only limited, mission-related services, significantly reduces manpower requirements. Table 4 shows a Base Opening Package for a CMB.

Table 4.—Base opening package for a CMB [1]

Function	Officers	Airmen	Total military	Civilian	Total
Command	6	6	12	0	12
Maintenance	0	1	1	0	1
Weapon system security	0	59	59	0	59
BOS	0	122	122	21	143
Total	6	188	194	21	215

[1] Source: Hess, R-1439-PR, Table H-2, p. 49.

The second source of manpower savings is economies of scale within operating wings. As with a base, an operating wing must provide a variety of services whether it has one, two, or more aircraft squadrons associated with it. The initial personnel needed to provide these services represent a "fixed charge" for an operating unit; as additional UE are added they require proportionately less manpower. Table 5 illustrates this with manning requirements for one 14-UE squadron of B-52H aircraft alongside the additional manning required to add a second squadron.

Table 5 was generated as part of the Rand study by the BOMTAN model. It does not reflect manning for SRAMs or ALCMs. The Rand study also looked at other means of estimating manpower requirements for the RAA, such as SAC UDLs, SAC planning factors, and building units from the ground up. All the approaches produced comparable answers, giving us considerable confidence in using the results of the Rand study as a data source for this analysis.

The data in Tables 3, 4, and 5 are used extensively in this analysis. First we construct the manning requirements for the current structure, as shown in Table 6.

The manning in Table 5 assumes a 1.5 crew ratio and is reduced for this analysis to correspond to the current 1.3 crew ratio. Noncrew manning is adjusted upward to account for the increased activity rate of four sorties/crew/month for the current structure. This adjustment is based on a sensitivity analysis in the Rand study indicating that noncrew personnel would be increased by a factor of 1.12. To accommodate the nonstandard number of UE in most of the bomber squadrons, only the first 14

Table 5.—Primary program element (PPE) manpower for B-52H squadrons (Crew ratio = 1.5, ground alert rate = 43 percent, 2 sorties/crew/month)

	First squadron				Second squadron			
Item	Off.	Airmen	Civ.	Total	Off.	Airmen	Civ.	Total
Aircrew	105	21	0	126	105	21	0	126
Squadron admin.	5	3	0	8	5	3	0	8
Maintenance	8	467	13	488	5	257	7	269
Munitions	4	55	0	59	0	11	0	11
Weapon sys. sec.	1	160	0	161	0	52	0	52
Wing staff	34	62	4	100	16	29	2	47
Total	157	768	17	942	131	373	9	513

aircraft in any location are assigned manpower based on the "First squadron" requirements. Each additional aircraft is assumed to require only 1/14 of the manning for a second squadron. The resultant PPE (Primary Program Element) manning for the B-52G and H is shown in Table 6.

To the PPE manning must be added the variable base operating support (BOS) and personnel support (PS) manning required to support the operational units at the MOBs. These requirements are calculated using the BACE model in AFM 173-10. The final manning increments required are the Base Opening Package (BOP) requirements and the concomitant PS. For the B-52G, seven BOP increments are required. For the B-52H, only three BOP increments are required since two B-52H units are tenants on non-SAC bases. The total manpower requirements for the B-52G and H current structure are shown in Table 7.

It remains to compute the manpower requirements for the KC-135 under the current structure. Data of the form shown in Table 5 were not available for the KC-135 so actual manning data for KC-135 units at the bases listed in Table 2 were obtained. As a proxy for the difference in manning between first and subsequent squadrons, KC-135 units colocated on MOBs with bombers were used as representative of subsequent squadrons, while units not colocated with bombers were assumed to be representative of First Squadrons. This appears to be a reasonable approximation because of SAC's policy of predominance, which assigns manpower used jointly by bombers and tankers to the bomber unit. Thus a KC-135 unit colocated with a bomber unit will show only that additive manning beyond that provided by the bomber squadron. This approach results in an estimate of 33.1 men/UE required for an independent tanker squadron, and 23.5 men/UE for a colocated squadron. These numbers are conservative in that they show fewer economies of scale than a comparison of first and subsequent bomber squadrons. The manpower requirements for BOS, BOP, and PS are computed as before. The KC-135 is charged with only six Base Opening Packages for the current structure, since at all other bases it is either colocated with SAC

Table 6.—Current structure: primary program element (PPE) manning

Manning	B-52G	B-52H
Crews		
Officers	905	545
Airmen	181	109
Other		
Officers	495	323
Airmen	7070	4624
Civilians	162	106
Total	8813	5707

Table 7.—Manpower requirements: current structure

	B-52G	B-52H
PPE		
Officers	1,400	868
Airmen	7,251	4,733
Civilians	162	106
Total PPE	8,813	5,707
BOS and PS		
Officers	154	95
Airmen	1,739	1,128
Civilians	257	167
Total BOS and PS	2,150	1,390
BOP and PS		
Officers	332	142
Airmen	5,694	2,440
Civilians	2,457	1,053
Total BOP and PS	8,483	3,635
Total, all manning	19,446	10,732

bombers or is a tenant on the base of another command. Table 8 shows the manpower requirements for the KC-135 under the current structure.

The manpower requirements for the RAA are computed in much the same way as for the current structure. Under the RAA each SMB will require full PPE manning for only one First Squadron, with the remaining UE manned at the rate for subsequent squadrons. The KC-135s based at MOBs and at the B-52H SMB are also manned at the rate for subsequent squadrons, since they are colocated with bomber elements. There will also be additives, under SAC policy, for those aircraft standing alert away from home base. Thus the PPE manning for each SMB includes one additional crew for each six aircraft on alert away from home, three additional maintenance men for each bomber/tanker pair on alert at a CMB (this increment is assigned to the bomber SMBs in accordance with SAC's policy of predominance), plus one additional munitions man for each bomber on away-from-home alert. The total PPE manpower requirements are then used to compute BOS and PS requirements. Finally, each SMB requires a Base Opening Package and additional Personnel Support, and each CMB requires its own smaller base opening package and personnel

Table 8.—KC-135 manpower requirements: current structure

PPE	
Officers	2,878
Airmen	8,372
Civilians	172
Total PPE	11,422
BOS and PS	
Officers	310
Airmen	2,191
Civilians	334
Total BOS and PS	2,835
BOP and PS	
Officers	283
Airmen	4,881
Civilians	2,105
Total BOP and PS	7,269
Total, all manning	21,526

support (shown in Table 4). Additional Direct personnel and Base personnel required by the CMBs will be TDY'd from the SMB. Thus, these manpower estimates were included in the SMB manpower estimates. Table 9 shows the total manpower requirements of the RAA structure.

Comparisons of Tables 7 and 8 with Table 9 show that the RAA requires about 18,000 fewer people than the current structure. Of this figure, over 60 percent is attributable to basing requirements with about 30 percent of the savings coming from PPE manpower.

The annual manpower costs of the two structures is obtained by using standard pay and allowance factors for FY 78 from AFM 173-10. The crews are costed at rated officer and airman rates, with remaining military and civilian personnel costed appropriately. The results are shown in Table 10.

The projected manpower savings alone are close to a quarter of a billion dollars a year. This is in the same ballpark as the original Rand study in spite of basing

Table 9.-RAA manpower requirements.

	B-52G	B-52H	KC-135
PPE			
Officers	1,249	762	2,644
Airmen	4,755	3,024	7,691
Civilians	101	65	157
Total PPE	6,105	3,851	10,492
BOS			
Officers	140	86	314
Airmen	1,194	754	2,051
Civilians	179	113	307
Total BOS and PS	1,513	953	2,672
BOP and PS			
SMB			
Officers	47	47	94
Airmen	814	814	1,628
Civilians	351	351	702
CMB			
Officers	40	26	26
Airmen	1,207	805	805
Civilians	129	86	86
Total BOP and PS	2,588	2,129	3,341
Total			
Officers	1,476	921	3,078
Airmen	7,970	5,397	12,175
Civilians	760	615	1,252
Total, all manning	10,206	6,933	16,505

changes made since that study was done. Although the basing changes reduced manpower savings by some consolidation of MOBs, the annual cost of manpower has increased rapidly, offsetting the reductions in manpower. If manpower costs continue to rise, as is most likely, these economic advantages of the RAA will be even more striking in the future.

Table 10.—Manpower cost comparison (in $ million)

Item	Current structure	RAA	Difference
PPE	327.239	267.371	59.868
BOS and PS	74.678	61.140	13.538
BOP and PS	258.248	95.752	162.496
Total	660.165	424.263	235.902

COMPARISON OF SPARES COSTS

Under the RAA essentially all maintenance and all supply transactions will occur at the SMBs. This will reduce stockage costs in several ways. There is a direct savings in spares safety level requirements by consolidating stockage requirements at four SMBs from 20 MOBs. Although we were unable to get an estimate of these savings for the KC-135, we have made an estimate for the B-52Gs and Hs. Using the DO-41 data base for all recoverable items on the B-52G, Chapter 11 stock level computations were made to determine the spares required for the RAA and the current structure. Two cases were run. The first compared B-52G requirements for one SMB supporting 139 aircraft with requirements for seven MOBs. The B-52G data were also used as a proxy data base for comparing the B-52H SMB requirements for 84 aircraft against five MOBs. The results showed not only a substantially decreased spares requirement in both cases, but also a significant reduction in backorders (a backorder occurs when an item is required to repair an aircraft but is not available from supply; reduced backorders thus equate directly to increased operationally ready aircraft). Two more runs were made to determine what spares level was required to support the aircraft at an operationally ready rate equivalent to the current structure. In these runs the number of spares for the RAA structure was minimized subject to the constraint that backorders for every item be equal to, or better than, backorders in the current structure. The results of these runs are shown in Table 11.

Because of the "less than or equal to" constraints on backorders, the optimized spares case for the RAA still incurs only 40 percent of the backorders for the current case for both the B-52G and B-52H. Yet the RAA requires $36.4 million less in spares than the current structure. This considers the B52-G/H force only. Similar improvements would occur for the KC-135 fleet.

Since the spares have already been bought for the B-52, this may appear to be a false saving since the excess spares could not be sold off to recoup the dollars already

Table 11.—Comparison of spares costs and backorders: RAA vs current structure (Costs in $ million)

	B-52G			B-52H		
Item	Current structure	RAA chap. 11	Equal back-orders	Current structure	RAA chap. 11	Equal back-orders
Spares cost	$48.550	$28.112	$25.702	$30.958	$18.967	$17.433
Backorders	209	44	81	147	39	61

spent. However, the B-52 has a significant replenishment spares budget, estimated to be about $35 million in 1980. Adoption of the RAA would allow this budget to be reduced the first year or two of RAA operation, and all or most of the savings could be attained in this manner. Most important, the RAA would provide much better supply support than the current system even with fewer spares.

Although we were unable to quantify the effects in the timeframe available for this case study, the RAA can be expected to reduce spares requirements and improve performance in other ways as well. The scale of workload in maintenance at the SMB can be expected to improve the base repair capability so that fewer items need to be sent to the depot for repair. This was one of the effects documented in the evaluation of the PACAF Centralized Intermediate Repair Facility (CIRF) and was attributed to the increased scale of that facility over a normal base. It significantly reduced the spares in the depot pipeline and thus reduced overall stockage requirements. The same effect can be expected with the RAA even though its magnitude will be difficult to estimate.

One final effect of the RAA concerns those reparable items that are coded for depot repair only because of the expensive equipment or specialized skills needed for their repair. Under the RAA, with the increased scale at the SMB and the decrease in number of base repair locations, many if not all of those items might be repaired at the SMB, since it will be more economically feasible to provide the equipment and skills at a limited number of locations. This may not affect the B-52 significantly since the depot repair equipment is already purchased and additional equipment to set up both SMBs with repair capability may be impractical. However, it has striking implications for the ALCM. Under the RAA the base level repair of the ALCM occurs only at the two bomber SMBs. By buying two sets of depot repair equipment for the ALCM rather than one, essentially all "depot" repair could be done at base level, obviating the need to buy spares to compensate for the depot pipeline. This could appreciably reduce the spares buy for the ALCM.

To determine the magnitude of the migration of repair from the depot, the DRMS tasked AFLC to conduct an illustrative ORLA study of 43 items used on the B-52G. The items selected for analysis were ones that generate a high dollar volume of depot repair work. This study showed that if only two intermediate maintenance facilities were used to repair these items, that between 60 percent and 98 percent of the items should be repaired at the intermediate level, whereas with 9 intermediate repair locations between 14 percent and 65 percent of the items would be repaired at the intermediate level. Although this ORLA study was only illustrative, it clearly supports the DRMS premise that work would migrate from the depot to the intermediate level if the number of intermediate maintenance facilities is reduced. The Appendix presents details of the ORLA study conducted by AFLC (AFALD/XRS) for the DRMS.

FACILITIES COSTS FOR THE RAA

Accurately estimating the size of the facilities investment requires a bed-down of the force as an input, so that the estimate can be put together base by base. The total investment is clearly a function of the number of SMBs. It is not a linear function, since several bases already have populations (either in UE or people) greater than or about the size of an SMB. For example, the B-52G SMB is forecast to require about 9000 people. Andrews, Davis-Monthan, Eglin, Lackland, Langley, Offutt, and Travis all have over 9000 as a base population. At least ten other bases have more than 7000. In terms of aircraft population, Grissom has 91 UE, Travis has 91, Plattsburgh has 76, and Barksdale 84. These bases, though they are not a single MDS nor operating like an SMB, do provide some relevant experience. The point is not that these are necessarily potential SMBs, but that the size of an SMB, though clearly on the high side of current MOBs, is not outside the experience of operating commands. If we consider only a sample of the facilities required, such as ramp space and runways 10,000 by 300 feet or greater, there are five SAC bases that currently have the required runway and ramp space for 60 or more B-52s (at 13,000 square yards per aircraft). It is clear that the investment would go toward modifying existing facilities, rather than building brand-new ones. Though it is true that a sizable one-time investment can be justified by the large annual savings forecast, we recognize the problem of spending money on the promise of future savings. The natural, phased implementation that this type of concept requires might go a long way to make this an easier problem. The first SMB could by design require the least investment.

A 1974 Rand study addressed the costs of converting selected SAC bases to SMBs. These are provided in updated format here strictly as a *rough* approximation of additional facilities costs for the RAA.

The Rand study assumes that Blytheville AFB represents the facilities requirements for a 30-UE unit. The requirement for each class of facility on an SMB is determined by dividing the like facilities available at Blytheville by 30 and multiplying the result by the number of UE assigned at the SMB, adjusted by an efficiency factor. Facilities categories considered were runways, ramps, hangars, maintenance, and administration/operations. The top line of Table 12 shows the representative data on facilities at Blytheville. For this comparison Barksdale AFB was designated the B-52G SMB, Carswell AFB as the SMB for the B-52H, and Fairchild AFB and Plattsburg AFB as KC-135 SMBs. For each of the candidate bases, Table 12 shows the required facilities based on the number of aircraft assigned to the SMB, the available facilities at each, and the shortfall. The cost of construction to remedy the shortfall is also listed (in FY 1974 dollars).

Table 12.—Estimated facilities costs for the RAA.

	Base	U.E.	Runways[1] (number)	Ramps (sq. yds.)	Hangers (sq. ft.)	Maintenance (sq. ft.)	Admin/OPS (sq. ft.)
(Reference)	Blytheville	30	1	794,002	218,339	271,523	214,483
B-52G SMB	Required	99	2	1,865,024	647,063	804,677	494,996
	Barksdale		1	1,546,104	506,155	832,575	801,955
	Shortage		1	318,920	140,908	0	0
	Cost[2] ($M)		16.0	9.568	4.931	0	0
B-52H SMB	Required	79	1	1,381,459	524,097	651,760	395,907
	Carswell		1	930,656	452,489	409,269	565,439
	Shortage		0	450,883	71,608	242,491	0
	Cost[2] ($M)		0	13.524	2.506	6.062	0
KC-135 SMB	Required	99	2	1,316,068	644,033	800,909	495,456
	Fairchild		1	1,213,623	1,053,284	1,354,044	647,735
	Shortage		1	102,445	0	0	0
	Cost[2] ($M)		16.0	3.073	0	0	0
KC-135 SMB	Required	100	2	1,329,362	650,538	808,999	500,461
	Plattsburg		1	1,233,358	477,014	463,785	452,775
	Shortage		1	96,004	173,524	345,214	47,686
	Cost[2] ($M)		16.0	2.880	6.073	8.630	2.146
Total costs ($M)			48.0	29.045	13.510	14.692	2.146

1 For this analysis it is assumed that the B-52H SMB requires only one runway, with all other SMB's requiring two runways.

2 Runway costs are from R-1439-PR, other costs from "Estimating the Cost of Relocating Military Bases," (RM-5585-ISA) updated to 1974 dollars by Al Barbour.

Appendix D
BASE OPENING PACKAGE COST

Manpower cost/military includes PCS travel, quarters, retirement, training, and support costs, plus dependency and indemnity compensation, unemployment compensation, educational benefits, and income tax adjustment.

Civilian cost includes overtime and holiday pay, retirement, life insurance, health benefits, terminal leave, training, workmen's compensation, and unemployment compensation.

Source: *USAF Cost and Planning Factors Manual (U), AFM* 173-10 (Confidental).

Appendix D.—Base opening package cost

Manpower cost of personnel—Air Force

Officers:	$32,877/year
Airmen:	$15,733/year
Civilians:	$20,654/year

Officers	(71)	($32,877)	=	$ 2,334,267
Airmen	(755)	($15,733)	=	$11,878,415
Civilians	(371)	($20,654)	=	$ 7,662,634
Total	1197			$21,875,316

Appendix E
A-10 OPTIMUM LEVEL OF REPAIR (ORLA) STUDY

The Air Force Logistics Command (AFALD/XRS) conducted an illustrative ORLA study for the DRMS on a sample of 69 A-10 items that generate a high dollar volume of depot repair work. It should be emphasized that this was just an illustrative study which showed that as the number of intermediate repair activities is decreased, the number of items that should be repaired at the intermediate level increases. Three different series of runs were made to determine the sensitivity of the level of repair decision to the amount of technical training necessary and the amount of support equipment required to establish a repair capability for the item at the intermediate level.

The first series of runs included the cost of twelve weeks of technical training and $10,000 in additional support equipment. The second series of runs included 25 weeks of technical training and $50,000 of test equipment. In the third series of runs the technical training requirement was increased to 52 weeks and the support required increased to $100,000. All three ranges of increases in investment are per item repaired and are referred to as the Low, Medium, and High Investment cases. The results of these runs are summarized in Table E-1.

Table E-1.—Summary of ORLA study of 69 A-10 items

	Low investment [1]			Medium investment [2]			High Investment [3]		
No. of bases	Depot repair	I level repair	Base discard	Depot repair	I level repair	Base discard	Depot repair	I level repair	Base discard
1	0	60	9	0	51	18	0	50	19
2	26	33	10	34	16	19	40	9	20
3	37	22	10	40	10	19	45	4	20
5	48	11	10	43	7	19	49	0	0
6	49	10	10	46	4	19	49	0	20
8	51	8	10	46	4	19	49	0	20
10	53	6	10	48	2	19	49	0	20

[1] Low investment = $14K technical training cost + $10K support equipment cost
[2] Medium investment = $30K technical training cost + $50K support equipment cost
[3] High investment = $80K technical training cost + $100K support equipment cost

The data in Table E-1 illustrates that as the number of intermediate maintenance activities is decreased, the number of items repaired at the intermediate level increases. However, if a high level of investment in acquiring skills and additional support equipment is incurred, the migration of repair from the depot to the intermediate level is less pronounced. Each item analyzed was then categorized as to cost and activity rate (activity rates were based upon mean time (in operating hours) between demands). These cost/demand categories were established using criteria outlined in Table E-2.

The 69 A-10 items analyzed were then aggragated using these categories and the resultant level of repair decisions are displayed in Tables E-3, E-4 and E-5 for three different levels of investments (i.e., low = \$24K, medium = \$80K, and high \$162K).

This illustrative case supports the DRMS premise that by reducing the number of intermediate maintenance facilities, more items could, from an economic standpoint, be repaired at the intermediate level. This migration of items to an in-theater repair facility would enhance the ability of a combat commander to support his forces. It would improve peacetime readiness and wartime sustainability. If the Air Force adopts the Forward/Rearward support concept, AFLC should, in conjunction with theater logistics managers, analyze repair decisions made under the traditional support concept and reevaluate these decisions taking into account the new support structure.

Table E-2.—A-10 ORLA cost/demand categories

Category	Cost	Mean time between demands in operating hours
L	≤ 3,000	≤ 300
M	≤ 10,000	≤ 2,000
H	> 10,000	> 2,000

Table E-3.—ORLA analysis 69 A-10 reparables: low investment required to establish intermediate repair capability[1]

No. of Bases	1			2			3			5			6			8			10		
Cost/demand category	D[2]	I[3]	B[4]	D	I	B	D	I	B	D	I	B	D	I	B	D	I	B	D	I	B
LL		1			1			1		1			1			1			1		
LM		12		8	4		11	1		12			12			12			12		
LH		9	7	7		9	7		9	7		9	7		9	7		9	7		9
ML		3	1		3	1		3	1		3	1		3	1	1	2	1	1	2	1
MM		22	1	6	17		11	12		19	4		20	3		21	2		21	2	
MH		6		4	2		6			6			6			6			6		
HL		4			4			4		1	3		1	3		1	3		1	3	
HM		1			1			1			1			1			1		1		
HH		2		1	1		2			2			2			2			2		
Total	0	60	9	26	33	10	37	22	10	48	11	10	49	10	10	51	8	10	53	6	10

[1]Investment in technical training and support equipment assumed to be $24K per item.

[2]Depot repair.

[3]Intermediate repair.

[4]Discard at base (no repair).

Table E-4.—ORLA analysis 69 A-10 reparables: medium investment required to establish intermediate repair capability[1]

No. of Bases	1			2			3			5			6			8			10		
Cost/demand category	D[2]	I[3]	B[4]	D	I	B	D	I	B	D	I	B	D	I	B	D	I	B	D	I	B
LL		1			1			1			1			1			1			1	
LM		11	1	10		2	10		2	10		2	10		2	10		2	10		2
LH		1	15	1		15	1		15	1		15	1		15	1		15	1		15
ML		3	1		3	1	1	2	1	1	2	1	2	1	1	2	1	1	3		1
MM		23		15	8		20	3		22	1		23			23			23		
MH		5	1	5		1	5		1	5		1	5		1	5		1	5		1
HL		4		1	3		1	3		1	3	8	2	2		2	2		3	1	
HM		1			1			1		1			1			1			1		
HH		2		2			2			2			2			2			2		
Total	0	51	18	34	16	19	40	10	19	43	7	19	46	4	19	46	4	19	48	2	19

[1]Investment in technical training and support equipment assumed to be $80K per item.

[2]Depot repair.

[3]Intermediate repair.

[4]Discard at base (no repair).

Table E-5.—ORLA analysis 69 A-10 reparables: high investment required to establish intermediate repair capability[1]

No. of Bases	1			2			3			5			6			8			10		
Cost/demand category	D[2]	I[3]	B[4]	D	I	B	D	I	B	D	I	B	D	I	B	D	I	B	D	I	B
LL		1		1			1			1			1			1			1		
LM		9	3	9		3	9		3	9		3	9		3	9		3	9		3
LH		1	15	1		15	1		15	1		15	1		15	1		15	1		15
ML		3	1	1	2	1	2	1	1	3		1	3		1	3		1	3		1
MM		23		18	4	1	21	1	1	22		1	22		1	22		1	22		1
MH		6		6			6			6			6			6			6		
HL		4		2	2		3	1		4			4			4			4		
HM		1			1			1		1			1			1			1		
HH		2		2			2			2			2			2			2		
Total	0	50	19	40	9	20	45	4	20	49	0	20	49	0	20	49	0	20	49	0	20

[1]Investment in technical training and support equipment assumed to be $162K per item.

[2]Depot repair.

[3]Intermediate repair.

[4]Discard at base (no repair).

LOGISTICS SUPPORT ALTERNATIVES FOR ARMY HELICOPTERS

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I. INTRODUCTION

The U.S. Army has about 8,000 helicopters with attack, combat assault, transport and medical evacuation missions. They are an integral part of the combined arms team and are critical to the mobility and firepower delivery capability of deployed Army forces. The level of logistics support—maintenance, supply, and transportation— will determine the availability and mission-effectiveness of these aircraft.

The annual operating and support costs associated with an active Army fleet of 5,500 helicopters is on the order of $1 billion. Some 22,000 uniformed Army personnel are dedicated to aircraft maintenance. Therefore, from the point of view of readiness, combat effectiveness, and budget impact, logistics support for Army helicopters is a critical and substantial factor. Recently, a number of changes in operational and support concepts and organization have been proposed, and many of them are in some stage of implementation.

This report documents the results of the DRMS case study of Logistics Support for Army Helicopters. The study explores the current and evolving logistics concepts, doctrines, organizational structure, and procedures for support of deployed combat forces, and the environment in which they would operate. The study suggests several changes that might be warranted. Emphasis throughout is on maintenance and repair parts supply support.

Because this report does not present the results of completed research, it does not recommend courses of action for implementation. The complex interrelationships among combat units and logistics support forces do not permit rational extension of these results beyond indicating whether or not the Army appears to be proceeding in the proper direction and identifying areas that warrant further consideration. Prior to any implementation, these ideas must be subjected to additional analysis and testing.

This report is organized into five major sections. This introductory section briefly describes the scope and purpose of the report. Section II briefly describes the environment and mission of Army helicopters, discusses a set of six principles which form the basis for currently approved Army logistics concepts for doctrine and planning, and explains why the DRMS feels these principles are appropriate. Finally, it describes the current structure in terms of its suitability in view of the expected environment and the principles. Section III identifies changes to the current system which would seem to provide more effective and efficient support to the combat forces during wartime. Section IV discusses Army scheduled aircraft maintenance and a promising test program for depot repair of T-53 engines. Section V summarizes the conclusions and observations and provides recommendations. The appendix provides a more detailed description of the current and evolving maintenance and supply system.

II. EVALUATION OF ARMY HELICOPTER LOGISTICS SUPPORT STRUCTURE

INTRODUCTION

Although the specifics of a realistic scenario for a Warsaw Pact/NATO conflict are unknown, some general characteristics are considered likely. The transition from peace to war will be hectic. During the initial period, armored thrusts will attempt breakthroughs to be exploited by highly maneuverable mechanized forces. Combat will be intense, pressure will be unrelenting day and night, and attrition will be very high. Combat units will need high mobility to blunt initial attacks, reinforce battered units, and reallocate scarce resources to points of greatest need. After the initial phase, the front will stabilize and units will need to be reconstituted and supported for a period of sustained combat.

Helicopters will participate in virtually every facet of the land battle: delivery of firepower, transport of assault troops, logistics resupply, reconnaissance, command and control, and medical evacuation. The helicopter makes a unique contribution to mobility, exploitation of firepower, integration of fire and maneuver, massing of forces, surprise, rapid displacement of forward elements, and flexibility to meet the demands of a high-threat scenario. Attack helicopters are a highly mobile and flexible means of massing anti-armor capability. Transport helicopters can rapidly move ground forces and logistics resources to exploit offensive opportunities or reinforce defensive positions. Observation and scout helicopters provide a responsive reconnaissance capability.

To take maximum advantage of these capabilities, helicopters must be available where and when they are needed. They must be dispersed for survivability, capable of massing for maximum effect, and capable of deploying rapidly to meet requirements across the combat theater. Continuous combat operations and limited numbers of helicopters imply a need for assigning priorities to requirements and striking a balance between the needs for near-term surge and sustained capability.

The objective of the restructuring of Army aviation proposed by the USAREUR Aviation Reorganization and ARCSA III (Aviation Requirements for the Combat Structure of the Army III) is to enhance Army aviation's effectiveness in a middle- or high-intensity tactical combat. The evolving combat structure reduces the number of separate units and locates them in a division or corps structure. It is believed that pooling assets into fewer units will increase aircraft availability while retaining a modular structure for flexibility. Aviation maintenance and supply organizations are being realigned from a four-level to a three-level maintenance structure; this will provide greater capability at the aviation company level, reduce the duplication of equipment and personnel skills at various levels, and increase the maintenance organization's responsiveness to needs in a combat environment. (See the Appendix for a more detailed discussion of the evolving maintenance and supply structure for Army Aviation.)

This restructuring is consistent with six principles that form the basis for currently approved Army Logistics Concepts for Doctrine and Planning:[1]

1. *Reducing the logistics burden on the combat forces in the forward combat area.*
2. Fixing combat-essential weapon systems as far forward as possible to maximize their contribution to the battle effort.
3. Consolidating application of logistics resources behind the forward battle area wherever possible to capitalize on economies of scale, and maximize the use of critical skills, tools and test equipment.
4. Assuring that logistics resources in theater are fully responsive to the needs of the theater commander.
5. Reducing to the minimum the theater commanders' initial dependence on CONUS depot support by increasing theater war reserve stock and ammunition consistent with their combat needs and management capability. Assuring that combat essential spares, emphasizing components and "black boxes," are on hand with theater forces to reduce initial dependency on CONUS support.
6. Reserving limited theater transportation resources for critical resupply and evacuation of repairable assets beyond their capability to handle in the forward area.

These principles appear to reflect many of the qualities essential for effective logistics support to tactical forces. They typify the direction in which the Army and the Air Force appear to be moving in order to respond to a mid- to high-intensity tactical combat environment where our resources are likely to be strained to the limit. The following provides the DRMS view of why these principles seem to be appropriate and why they should be reflected in the support structure.

PRINCIPLES FOR LOGISTICS SUPPORT

Reducing the logistics burden on combat units should enhance combat effectiveness, resource management effectiveness, and efficiency. It will heighten the unit's mobility and flexibility and its integrated logistics capability. The combat unit will no longer be burdened with moving large amounts of equipment, repair parts, and specialized personnel, which often require facilities for effective use that are not easily found in a forward combat area. Resource management effectiveness is increased by reducing the amount and kinds of resources that the combat commander has to manage. Management of combat aviation resources—personnel, materiel, and the logistics required to support them—has always been complex and is growing more so. Resource constraints will always force tough tactical decisions. It will help the combat commander if he can focus his attention on mission-essential factors. Increased efficiency results from better utilization of personnel and equipment and a common unit goal of generating immediate combat capability. Simplification of training, supervision, and

[1] Memorandum for Study Director, Resource Management Study, from Director of the Army Staff, 19 July 1978.

management tasks will produce efficient organizational structures tied to a single mission focus.

Fixing weapon systems as far forward as possible increases their combat availability. Evacuating a whole weapon to the rear for repair, instead of a failed component, reduces its availability in two ways. First, it is unavailable during the time it takes to obtain transportation and move it to the rear and back. Transporting a helicopter that is not flyable is a time-consuming task that may require disassembly, or at least some preparation to ready it for movement. Additional repair may also be required to correct damage incurred in transporting the helicopter. Secondly, repair in the rear may take much longer than it would in the operating organization, which may be motivated by a greater sense of urgency. In any event, it is quicker to transport the required component and a repair team, if required, to perform the repair forward when that is possible.

Consolidation of logistics resources behind the forward battle area not only relieves the burden on the combat commander, but also makes economies of scale possible. In many cases, specialized skills, tools, and test equipment would be underutilized if placed with the forward combat unit, since no unit generates enough workload to keep them busy all the time, even at peak demand. In other cases, even if fully utilized at peak demand, peak demands across a number of units occur at different times, so no one unit can fully utilize them all the time. Consolidation across units tends to smooth the total demand and uses scarce resources more efficiently. Consolidation behind the forward battle area increases the opportunity to use fixed or semifixed facilities, which are more productive. Maintenance personnel are not disrupted by the combat environment and the need to move periodically. (Army planning factors in AR 570-2, for example, increase man-hour availability by almost 25 percent when facilities are fixed.) Consolidation in the rear area is also more conducive to a production line capability, which would be virtually impossible in the forward area, and may open up possibilities for using special technology that would not be practicable forward. Complex test and repair equipment that require fixed facilities and a controlled environment may be much more productive in the rear and infeasible elsewhere.

It is vital that *in-theater logistics resources be fully responsive to the needs of the theater commander.* Priorities are likely to change rapidly in the early stages of a war, and outside control of resources will be less able to respond to changing needs. It takes time to communicate changing requirements through multiple levels of command, and more time to communicate changing priorities back down to theater resources. Because no one above the theater commander is likely to have additional information that would permit a "better" decision, he should have the authority and the means for reallocating resources already in the theater as well as those committed to the theater, even if they are still en route or not yet in transit. The means must include a logistics command and control and resource management system.

The theater must depend on its own resources during the initial phase of hostilities. According to the current planning scenario, the transition from peace to war will be hectic, transportation resources will be swamped, and lines of communication subject to disruption. Sufficient supplies must therefore be on hand at the outset. Combat-essential spares should consist of components and black boxes to support a remove-and-replace maintenance concept at the front to maximize weapon availability. A grounded helicopter is merely a target until a failed component can be replaced or repaired. Remove and replace is always faster and simpler than remove, repair, and replace, particularly if the repair must be done at a CONUS depot.

Transportation resources are used more effectively when they carry components in support of on-line maintenance instead of transporting weapons between the front and rear. The tonnage and cube is less, and evacuating weapons to the rear degrades operational availability.

These six principles, then, embody the characteristics required for an effective logistics support capability for Army helicopters as well as other tactical weapons. Recent and planned changes to Army aviation units and the logistics system supporting them are consistent with these principles and often demonstrate other qualities desirable in a tactical combat environment.

EVALUATION OF THE EVOLVING STRUCTURE

AVUM (Aviation Unit Maintenance) is integral to the aviation company, is responsible for most routine on-equipment maintenance, and uses a remove-and-replace concept for rapid aircraft turnaround. Failed components are evacuated to an AVIM (Aviation Intermediate Maintenance) unit located to the rear for repair. The AVIM assists AVUM with repair that is beyond AVUM capability because of peak workload demand or lack of required skills, equipment, or tools. Wherever possible, the AVIM does so by dispatching a contact team to assist the AVUM. Aircraft, or more usually components requiring repair beyond the capability of the AVIM, are evacuated to a depot facility.

The ARCSA III restructuring, which results in all aviation companies having ten or more aircraft, means that each aviation unit will have an AVUM capability. (Prior to restructuring, some units had fewer than 10 aircraft and did not possess an integrated AVUM capability. They relied on the supporting AVIM for other than organizational level maintenance.) This will relieve the AVIM from providing routine AVUM level support to the smaller units. Each unit will be capable of handling virtually all on-aircraft workload other than peak demand levels, using a remove-and-replace concept. Replacement components will be obtained from the supporting AVIM on a one-for-one direct exchange (DX) basis. The AVUM will also have a limited stock of high-demand parts in its Prescribed Load List (PLL). PLL stockage will also be obtained through the AVIM.

Conceptually, Army aviation maintenance organization and policy has a number of features that make it particularly well-suited for the tactical combat environment. Maintenance in the forward area is confined to routine servicing and rapid remove-and-replace actions. As discussed earlier, this concept tends to maximize the number of operationally ready aircraft, and is particularly effective where resources are constrained. Assigning the responsibility and the capability to accomplish most of the immediate mission-essential workload to the operational commander, rather than to a separate support element, motivates the unit commander to keep his equipment continuously maintained. He no longer has any incentive to run the equipment into the ground and then turn it over to "maintenance" for repair. He now has the responsibility and the incentive to balance immediate operational needs against longer-term aircraft availability.

Manning and equipping AVUM elements to handle something less than the total peak on-equipment workload and providing a backup capability in a supporting element (in this case, the supporting AVIM) tends to capture many of the efficiencies of a consolidated capability while retaining most of the virtues of a decentralized system. To the extent that the peaks for different aviation companies are sharp and noncoincident, the economies can be significant. To the extent the workload is constant (i.e., no peaking of demand), or the peaks across units occur at the same time, economies will not exist for consolidated support. Of course, peaks can be smoothed by simply delaying work, allowing a backlog to develop to be worked off after the peak has passed. This option reduces aircraft availability. Consolidation also uses specialized tools and personnel skills more efficiently where no one unit generates enough workload to fully utilize them, but several units do.

Implicit in Army maintenance philosophy is the concept that all maintenance elements directly supporting forward combat elements should assign priorities to work according to a rule of Shortest Remaining Processing Time First. That is, a maintenance element should give top priority to the aircraft that can be returned to operation the soonest. It can be shown that this rule excels all others in maximizing the number of available aircraft. It also ensures that aircraft which, because of peak demand, require backup assistance and have to wait for a contact team from the supporting maintenance unit, are aircraft with the longest repair times.

The division AVIM provides backup support for divisional units with AVUM capability. Under the new structure, the division AVIM company falls under the division's Combat Aviation Battalion rather than under the Division Support Command (DISCOM). Here again, having the maintenance element responsible for providing backup on-equipment support to the AVUM elements assigned to the operational command channel is advantageous in allocating scarce resources based upon operational mission requirements, yet balanced by the need for longer-term aircraft availability. "Logistics support" organizations tend to evolve procedures and policies that are conducive to "efficient" logistics support, but are not always responsive to the needs of a tactical combat organization operating in a dynamic environment. For combat organizations (the assumption here is that the division is essentially a combat organization whose main focus should be on combat effectiveness), it may be somewhat less efficient to possess immediate mission-essential logistics support, but it is more responsive to combat requirements. Care must be taken, however, that the combat commander is not burdened with less essential logistics activities.

III. AN ALTERNATIVE LOGISTICS SUPPORT POSTURE

INTRODUCTION

Currently, division AVIMs possess a limited component repair capability. A review of Army aviation logistics doctrine, and interviews with personnel on the Department of the Army staff and in USAREUR, have made it obvious that in the early month or two of a European conflict most maintenance resources below corps level, and even many corps resources (to include AVIM personnel), will be devoted to quick turnaround of unserviceable aircraft. This turnaround will consist almost exclusively of removal and replacement of components that can be quickly changed in a combat field environment. The environment, lack of WRM (War Reserve Materiel) aircraft, and the need for swift aircraft turnaround necessitates such measures as remove-and-replace, cannibalization, and recovery of downed aircraft, and effectively precludes component repair in the forward combat area. The need for rapid mobility of division assets precludes stocking the wide range of repair parts required to support extensive component repair within the division. These factors all indicate a potential benefit in reorienting the mission of the division AVIM and deleting the component repair mission. The division "AVIM" would then concentrate on its priority mission of backup to the AVUMs, using the remove-and-replace concept, with spares being repaired behind the division either in corps, in the COMMZ, or in CONUS.

ALTERNATIVE MAINTENANCE CONCEPT

In concept, this alternative would define the missions of the division "AVIM" as providing a backup maintenance capability for the AVUMs, maintaining the Operational Readiness Float (ORF), and maintaining the division's combat Authorized Stockage List (ASL). All specialists, special tools and equipment, and repair parts presently authorized for component repair in division AVIMs would be removed from the MTOEs. The "AVIM" would be manned and equipped to perform on-equipment work to augment the AVUMs. Personnel and equipment no longer required would be used to augment existing theater-level component repair capability.

Deleting the component repair mission from the division AVIMs appears to offer a number of benefits. It would reinforce the combat/operational focus of the division's Combat Aviation Battalion by embracing a total remove-and-replace maintenance philosophy for all division aviation maintenance elements. The primary mission of the division AVIM—providing a backup capability for the AVUMs—is retained and reinforced through deletions of the limited component repair capability, which appears to be little needed in peacetime and not planned for use during the initial stage of conflict. The battalion commander would be able to satisfy immediate mission-essential needs without being burdened with component repair, which, given an adequate supply of components, is a secondary mission.

Removing the associated equipment, specialized skills, and repair parts would increase the division's mobility and ability to react to changing requirements. Supply stockage would consist exclusively of spare components and modules that are conducive to removal and replacement in the field. There would be no requirement to stock the numerous lines of small repair parts, kits, and bits and pieces of bench stock needed for component repair. There would be an increased requirement to stock components and modules to support a remove-and-replace concept. What the difference would be in terms of weight and cube has not been quantified. Certainly, the total number of line items would be less. The impact on weight and cube may not be great, since demands for bits and piece parts varies much more than it does for components, and much of the current stockage is safety stock to protect against long pipeline times back to the CONUS. Managing the reduced number of lines of larger items should also be easier than managing the much larger number of small items. The division maintenance element would possess the personnel and equipment needed for highly mobile contact teams, which would be quickly deployable by helicopter or small truck. All other equipment would be deleted from the division "AVIM" TOE.

Consolidating the component repair capability further to the rear would increase the total theater component repair capability through better utilization of scarce specialists, tools and equipment, and repair parts. For example, component repair could be accomplished in fixed facilities with tools and equipment that, while more productive, are not sufficiently mobile to be included in division AVIMs or which are too expensive to replicate in every division. Increasing the theater-level component repair capability decreases the number of components that must be returned to CONUS depots for repair and increases the number of spares available in theater because of the faster turnaround of reparables.

This discussion tends to oversimplify the dichotomy between on-equipment maintenance and component repair. Clearly, some component repair capability will always exist within the AVUMs for such tasks as replacement of fuses and knobs, which do not require special equipment. An item-by-item analysis and construction of the Maintenance Allocation Chart and TOEs is needed to define in detail the implementation of the overall concept. This detailed analysis is beyond the scope of this study. We have tried to do a rough macro-level analysis to both illustrate the concept and provide an order of magnitude estimate of the potential impacts.

MAINTENANCE MANPOWER IMPLICATIONS

We first assumed that the skill mix reflected in current AVUM TOEs [i.e., the mix of helicopter repairmen (MOS 67), component repairmen (MOS 68), and Avionics, fire control and armament repairment (MOS 68 or 35)] is the correct skill mix required for on-equipment work using a remove-and-replace concept. We also assumed that the number of helicopter repairmen in the division AVIM TOEs adequately reflects the on-equipment workload of the division AVIM. Given these two assumptions, it is then possible to estimate the number of component repair specialists required in the division "AVIM" to support AVUM using a remove-and-replace concept.

Table 1 summarizes relevant TOE information for an infantry division as contained in Army Field Manual 1-15, *Aviation Reference Data*, dated 30 September 1977. The number of repairmen in MOS 67 was reduced by one-half of the flying crew chiefs authorized, since only one-half of the flying crew chief's time is available for maintenance per AR 570-2. Based on the above assumptions, the ratio of component repair specialists to helicopter repairmen for an AVIM without a component repair mission would be 0.46 rather than 1.23. This would result in a requirement for 27 component repair specialists (0.46 x 59) rather than the 65 contained in the TOE. This reduction of 38 component repairmen represents 32 percent of the maintenance personnel and 20 percent of the total AVIM TOE.

Using the TOE data has the advantage of capturing organizational structure effects, but it has the disadvantage of reflecting out-of-date MACRIT factors. It has an additional disadvantage in that some of the division units do not presently possess a full AVUM capability as will presumably be the case after the small units are consolidated into a division aviation company. To test the impact of these constraints, a second set of calculations were done using the MACRIT factors contained in the November 1977 update. Table 2 shows the relevant MACRIT data and the ratios of component repairmen to helicopter repairmen. These factors show the number of maintenance personnel per aircraft authorized based upon the planned wartime flying-hour program, and other policies and procedures in AR 570-2. The factor for MOS 67 for UH-1s has been adjusted to account for the fact that each flying crew chief is expected to devote only 50 percent of his time to maintenance activities. These data indicate a much sharper difference between the AVUM and AVIM ratios than did the TOE data. Table 3 shows the AVIM' factors calculated by using data from Table 2 for MOS 68.

Using these differences, we then calculated the impact on an infantry division TOE and the Armored/Mechanized Infantry TOE based on the number of aircraft authorized in the respective divisions.

Table 1.—Infantry division TOE data

Aircraft:				
AH-1	33			
UH-1	65			
OH-58	62			
Total	160			
Personnel with MOS 67, 68, and 35:		AVUMs	AVIM	Total
Total personel		587	118	795
Discounting flying crew chiefs by ½		555	118	673
Helicopter repairmen (MOS 67)		381	59	440
Component repairmen (MOS 68 and 35)		174	65	239
Ratio of helicopter repairmen to component repairmen		0.46	1.23	0.65

Table 2.—Aircraft maintenance MACRIT factors

MOS	AVUM			AVIM		
	AH-1	UH-1	OH-58	AH-1	UH-1	OH-58
Helicopter repairmen (MOS 67)	1.74	1.83[1]	1.21	0.32	0.39	0.27
Component repairmen (MOS 68)	0.23	0.23	0.25	0.29	0.31	0.34
Total	1.97	2.06	1.46	0.61	0.70	0.61
Ratio, MOS 68/MOS 67	0.132	0.126	0.207	0.906	0.795	1.259

[1]Discounts 0.5 for flying crew chiefs.

Table 3.—Calculated AVIM MACRIT factors

Acft	AVIM MACRIT, MOS 67	AVUM MACRIT; ratio, MOS 68/MOS 67	AVIM' MACRIT, MOS 68
AH-1	0.32	0.132	0.04
UH-1	0.39	0.126	0.05
OH-58	0.27	0.207	0.06

Table 4 shows the difference between the updated AVIM *MACRIT factor* for MOS 68 and that calculated in Table 3 for an AVIM', i.e., a division AVIM without a component repair mission.

The data in Table 5 indicate that, using the MACRIT factors, a standard infantry division AVIM and one designed without a component repair mission would differ by 42 people, compared with the 38 calculated using the TOE data.

Table 6 shows the difference for a typical USAEUR armored or mechanized infantry division, which has fewer aircraft than the infantry division, and a different mix of aircraft. In this case the data indicate a difference of 32 people.

Table 4.—Comparison of MACRIT factors for MOS 68

Acft	AVIM	AVIM'	Difference
AH-1	0.29	0.04	0.25
UH-1	0.31	0.05	0.26
OH-58	0.34	0.06	0.28

Table 5.—Infantry division impact

Acft	No. of Acft	MACRIT	Personnel
AH-1	33	0.25	8
UH-1	65	0.26	17
OH-58	62	0.28	17
Total	160		42

Table 6.—Armored/mechanized infantry division impact

Acft	No. of Acft	MACRIT	Personnel
AH-1	42	0.25	10
UH-1	43	0.26	11
OH-58	41	0.28	11
Total	126		32

Based upon these estimates, 30 to 40 component repair specialists, related shop equipment, and spare parts would be available from each division to augment the nondivisional AVIMs' component repair capability.

Consolidating the component repair capability further to the rear would increase the component repair capability in the theater through better utilization of scarce specialists, tools and equipment, and repair parts. For example, component repair could be accomplished in fixed facilities with tools and equipment that, while more productive, are not sufficiently mobile to be included in division AVIMs or which are too expensive to replicate in every division. Based upon planning factors in AR 570-2, operating in a fixed facility would increase worker productivity by almost 25 percent merely through increased man-hour availability. Thus, 33 people relocated from a division AVIM to a fixed facility in the rear would equal the availability of 41 people in a division AVIM.

The gain in effectiveness is likely to be higher than 25 percent, however. The 70th Transportation Battalion (AVIM) at Coleman Barracks in Europe currently provides AVIM level support for all CH-47s in theater. Additional CH-47 companies are to be stationed in Europe. In considering options of where AVIM level support would be provided, planners arrived at one estimate that increasing the capability of the 70th would require 50 fewer people than if each corps were given its own CH-47C AVIM capability. Part of the difference was due to using local nationals at the 70th versus soldiers at the corps. Doing component repair in the rear opens the option of using civilians, which is certainly precluded if it is done in the division. The increase in overall theater-level repair capability would offset to an unknown extent the increased stockage level of component spares in the divisions.

Increasing theater-level component repair capability decreases the number of components that must be returned to CONUS depots for repair. Shortening the average pipeline time significantly increases the spares available in theater. For example, decreasing the average pipeline time for T-53 and T-55 engines by one day in wartime is equivalent to having an additional $1.50 million worth of spare engines. The Army DARCOM report (Depot Roundout for Aviation Study) estimated a pipeline savings of $42.969 million for one AVCRAD (Aviation Classification Repair Activity Depot) with 200 direct production personnel. (Each AVCRAD would have 336 personnel of which 200 are direct-production.) Increasing the ability to turn components around in theater rather than returning them to CONUS for repair saves on the order of 95 days in pipeline time. In addition, greater theater self-sufficiency is a hedge against disruption or temporary loss of the theater/CONUS lines of communication and the current heavy reliance on the ALOC (Air Line of Communications) to provide Class IX repair parts to Europe.

If the preliminary calculations for the infantry division are confirmed, and if the same proportional impact is found to apply across the Army aviation force structure, withdrawing component repair capability from division AVIMs would free 630 to 850 component repairmen for reassignment to nondivisional AVIMs. If these personnel were assigned to a fixed facility, the 25 percent increase in availability alone would be equivalent to adding 160 to 212 repairmen to existing division AVIMs. To the degree this increase in capability can be utilized to decrease overall pipeline time, additional assets can be made available to units to support a remove-and-replace concept within the division. The Depot Roundout Study, for example, concluded that 200 additional direct labor personnel in an AVCRAD could generate the equivalent of $43 million worth of additional assets under wartime conditions in Europe. This capability, plus prepositioning in Europe additional WRM stocks presently located in CONUS, would significantly enhance combat support for helicopter operations.

Supply and Transportation Implications

For either this alternative or the current concept to be most effective, higher levels of spares are needed in the theater. Currently, repair parts stockage in units is based on peacetime demand, not anticipated wartime demand. (There is a shortfall of over $38 million in aircraft repair parts in Europe against currently identified prepositioning requirements. Additional assets are being repositioned in Europe to eliminate this shortfall.) One alternative would be to preposition War Reserve Spares Kits (WRSK) for each unit. The WRSK would contain only wartime mission-essential spares for some period of time, say 15 days. For example, a recent study of SOTAS, which uses a modified UH-60 Blackhawk helicopter as the airborne platform, indicates that a 3-aircraft unit with a WRSK has better mission effectiveness and a lower life-cycle cost than does a 4-aircraft unit. The WRSK, plus the peacetime stockage, would support a remove-and-replace capability at unit level. Additional components would be stocked in theater war reserves at whatever depth is required to support wartime consumption rates, given the expected repair cycle times, etc.

Two additional elements are critical to the successful operation of any responsive theater logistics capability: logistics management and transportation. These two factors are even more germane to the scenario, environment, and the alternative maintenance and repair parts supply system discussed above.

A highly dynamic battlefield situation marked by frequently changing priorities and combat intensity for units, as well as significant differential disruption of resources at units due to combat damage, demands a management and control system which can both anticipate and react in near real time to changing demands. Currently, requirements calculations and supply distribution are based on fixed, forecasted activity rates and historical demand levels. Furthermore, the materiel management system depends upon surrogate measures to determine need. Thus, fill rate and backorder rate, for example, take on value unto themselves. There is an inherent assumption that all demands for a given item for a given system are of equal importance, remain relatively constant over time, and either change slowly or in response to planned events known well in advance. In a dynamic battlefield environment of a European scenario such preplanned priority systems will fail. There must be a system to deal with the differential importance of individual weapons, classes of weapons, units and missions as they vary over time. Functional proxy measures will not provide the intimate knowledge of mission requirements and resource capability to permit relevant allocation decisions. What is needed are more direct operational indicators based on fully explicated understanding of the local situation. This understanding is much more likely to reside in the theater and cannot reside in item managers located back in the CONUS.

In the dynamic environment, it is likely that serious resource imbalances will develop within units. These imbalances are likely to degrade unit capability. Thus, more routine reallocation of resources within the theater to the units where priority exists is likely to increase theater capability. This also implies that tasking and planning must be done using frequently updated status information. Given knowledge of both demand and supply, a more optimal use of theater resources can be obtained in terms of generating the kinds of combat capability needed, where needed and when needed within theater resource constraints.

The current Army theater materiel management system has limited responsibility and capability to satisfy these requirements. In addition to the normal logistics staffs, the system consists of the division MMC (Materiel Management Center), the corps MMC, and the theater MMC. The MMCs provide centralized and integrated materiel (supply and maintenance) management for all classes of military supply except medical, communications security, rail mission equipment, and classified maps.

The division materiel management center (DMMC) is a separate TOE unit assigned to the DISCOM headquarters. The DMMC consists of approximately 150 people primarily devoted to the management of division supplies. The DMMC: (a) determines requirements for development and technical supervision of division ASLs, PLLs and ORF lists, (b) procures all supplies received by the division for which the center is responsible and directs their distribution, (c) manages the division master property records and equipment status reporting system, (d) manages the class IX (repair parts) supply system including development, approval and maintenance of ASLs and PLLs, (e) operates an integrated maintenance management information program, (f) manages the class II supply system, and (g) determines ASL mobility requirements in time of war.

Two sections, the Class IX Supply Section and the Maintenance Section, manage the division's repair parts and maintenance resources. The Class IX Supply section receives, edits and forwards all repair parts supply requests from the maintenance battalion DSUs. It also develops and maintains the ASLs and monitors and publishes all PLLs.

The Maintenance Section is the centralized and integrated division maintenance management activity for all division equipment except Class VIII, communications security equipment, rail mission equipment, and classified maps. It manages both organizational and direct support maintenance. It operates the maintenance reporting and management system to maintain status information on combat-essential equipment and provides materiel readiness information. It develops maintenance plans for division combat operations, generates disposition instructions for unserviceables which exceed the repair capability or capacity of the division maintenance units, and develops requirements for transportation to evacuate unserviceables from the division area.

These elements certainly provide the nucleus and basis for a theater logistics management system of the kind we feel is required. The primary changes required for these elements appear to be the augmentation or development of the requirement information systems and procedures needed for the wartime mission. There appear to be major deficiencies, however, in the quantity of supplies available in theater and the physical means for handling and moving the supplies after they arrive in theater. The Army recognizes these deficiencies and has begun programming and budget actions to solve these problems.

Currently, there are insufficient repair part companies to handle the required repair parts flow. The Direct Supply System (DSS), in peacetime, directs repair parts from the depot to the requisitioning unit. In wartime, a much larger portion of the repair-parts flow must be handled at the Corps. This requires repair parts companies in the Corps. War reserve stock positioned in theater, stockage flowing through the corps, repair parts companies to handle the supplies, and augmented MMCs with the required information and procedures will provide the capability to weight the battle logistically and respond to dynamic changes in requirements if transportation is available to move the supplies to the point of need. Currently, the intra-theater transportation system is inadequate to meet planned requirements.

While repair parts are an insignificant fraction of the total transportation requirement, they are critical to combat capability. When viewed from the perspective of their criticality to and impact on weapon availability and in turn, combat capability, rather than the weight/cube magnitude, dedicated transportation assets may be warranted. For the alternative maintenance concept, which makes the individual combat unit almost totally dependent on a consolidated intermediate repair capability for components/assemblies, the already deficient transportation system becomes even more critical. Further study and test of these concepts must ensure that the required transportation can be made available to move the components/assemblies to the point of need and evacuate unserviceables to the repair facilities in a timely and responsive manner. Careful consideration should be given to the potential cost-effectiveness of a dedicated repair parts transportation system.

IMPLICATIONS FOR NON-EUROPEAN SCENARIOS AND CONUS PEACETIME ACTIVITY

For a number of reasons, most of the discussion in this paper has focused on Europe. Army aviation maintenance there is already organized into three levels. There is a precedent for a single AVIM supporting all AVIM component repair: the 70th Transportation Battalion provides all AVIM-level support for CH-47s in Europe. Europe is the current focus of much readiness/programming/budget attention. However, any reorganization such as the one we are proposing must also be judged by other criteria, including its ability to support CONUS-based units in peacetime and to adapt to wartime scenarios in other areas of the world.

Most CONUS-based units have not yet been reorganized under three-level maintenance. The 101st Air Assault Division at Fort Campbell, Kentucky, is an exception. The 101st has almost 450 helicopters authorized. Two AVIM companies provide intermediate level maintenance for division aircraft. In addition, Fort Campbell has one GS (General Support) aircraft maintenance company, manned by soldiers who provide area GS level support. An alternative would be to remove the component repair capability from the 101st AVIM companies, as proposed in the earlier discussion, and combine the component repair specialists with the GS company to form a nondivisional AVIM company with an area mission. The resulting AVIM company would then provide component repair support to the aviation companies at Fort Campbell as well as those at Fort Knox and elsewhere.

Similar high densities of aircraft occur in other areas of the country. A nondivisional AVIM at Fort Bragg could serve the 82d Airborne and other units in the area. A III Corps AVIM at Fort Hood could conceivably support the more than 1,000 helicopters in Texas, Kansas, and Colorado. Other units could be constituted to provide component level repair for other areas of the country where there are large concentrations of aircraft. These units could be deployed to Europe or other theaters to augment the capability there. It should be recognized that these units might not be as mobile as currently constituted division AVIMs, but for Europe the personnel could be used to augment the existing units and facilities. For other contingencies, it might be well to retain one highly mobile unit—that is, a unit that can readily be airlifted to a contingency area with its equipment. This unit would support the unilateral Corps, for example. More analysis would have to be done to determine how many nondivisional companies are needed, where they should be located, and so on. In some areas it might prove better to rely on existing TDA units manned with civilians or on contractor operations, as presently exist at Fort Rucker, Alabama. This would partly depend on how many nondivisional AVIMs with component repair capability are required to support fully mobilized and deployed forces, and on transportation costs, pipeline costs, etc. It would at least seem feasible to support CONUS forces and other scenarios using the same basic concept.

IV. SCHEDULED MAINTENANCE AND DEPOT REPAIR

INTRODUCTION

Scheduled aircraft inspections and maintenance in the Army are performed at the unit level (AVUM) and at depot level (either at an organic Army depot or by contractor). The unit-level inspections and maintenance are primarily routine preventive maintenance (inspection and repair of worn items, lubrication, and replacement of time-change items that do not require extensive jigs, fixtures, or specialized equipment), while depot-level inspection and maintenance are primarily in support of more extensive maintenance and overhaul. The Army has made rather extensive changes to both of these inspection and maintenance programs over the past several years and further changes are planned for implementation over the next few years.

AVUM-LEVEL INSPECTIONS AND SCHEDULED MAINTENANCE

In 1973 a new inspection package was tested at Fort Campbell, Kentucky, on the UH-1 aircraft. The new package implemented a phased inspection system (as contrasted to the old periodic system), extended many inspection intervals, packaged the workload in smaller, more manageable work packages, and concentrated different phases in different parts of the aircraft. The results of the Fort Campbell test (Test versus Control) are shown in Table 7. Based on test results, the new inspection packages were implemented Armywide and a program was instituted to revise the inspection packages for all other Army aircraft. Currently, the phase inspection packages for the UH-1 are at 100-hour intervals with an 800-hour cycle. Each phase inspection should take 3 to 4 days and 100 to 105 man-hours, assuming no shortage of repair parts or required maintenance personnel and/or skill levels. In one case, we were told it was taking as much as 10 to 14 days and 150 to 170 man-hours. At the current flying-hour program, the UH-1 is due for a phase inspection every eight months.

DEPOT INSPECTION AND MAINTENANCE

As part of its implementation of an On-Condition Maintenance (OCM) philosophy, the Army has instituted an annual screening of aircraft to determine candidates for Programmed Depot Maintenance (PDM) and to prioritize those aircraft for induction into the depot. This annual screening program is called the Airframe Condition Evaluation (ACE) program.

ACE is a special annual evaluation consisting of an examination of the aircraft structure for symptoms of possible hidden defects together with an assessment of some overall system condition parameter. The ACE pertains principally to structural members that are replaceable at depot; it does not pertain to components replaceable in the field or to time-change items. The inspection phase (presently accomplished under contract by Dynalectron) is performed using a standardized ACE report form to

Table 7.—Project Inspect test results

Performance measure	Test vs control
Improved operational readiness	79.4 percent to 75.9 percent
Reduced maint manhours per flying hour	4.32 MHRS vs 4.97 MHRS
Reduced supply	
NORS	1 vs 1.40
Demands	1 vs 1.21
Quantity	1 vs 1.63
$ Value	$1 million
Mission reliability (pre-flight and in-flight aborts)	98.4 percent vs 98.5 percent

record results. There is a TSARCOM pamphlet for each Mission Design Series (MDS) which provides guidance on conducting the inspection, filling out the report form, etc. The report forms are submitted to TSARCOM where the information is keypunched. A weighting factor is applied to each condition code and an overall aircraft score is computed. Any aircraft with a score above a predetermined cutoff level is then considered a candidate for PDM. Aircraft are then scheduled for PDM based on worst aircraft (highest score) first. This program has virtually eliminated aircraft going to the depot for PDM when nothing was wrong with them that could not be repaired in the field. In some cases, under the old system of scheduling aircraft for PDM based upon either flying hours or calendar time, aircraft previously went through an expensive PDM program when it was not needed, while aircraft needing PDM did not go simply because they had not flown as much or had recently completed their PDM.

The ACE program, coupled with more extensive preinduction inspection and repair only as necessary, has provided the data base and experience to effectively extend the depot intervals on Army aircraft. (Under ACE an interval does not exist in the same sense, but an average interval is imputed from the annual inductions compared to aircraft inventory.) Table 8 shows past and projected percentages of aircraft going through PDM, and the average intervals.

All aircraft depot maintenance is performed at Corpus Christi Army Depot (CCAD) or New Cumberland Army Depot (NCAD), or under contract as part of a modification program. NCAD has been doing CH-47s and OH-58s and some components, such as CH-47 rotor blades and OH-58 rotor heads. The OH-58 is no longer scheduled for overhaul and the CH-47 is programmed for a combined overhaul/modification under contract. All other organic aircraft depot maintenance is performed at CCAD.

Table 8.—Depot maintenance intervals

Aircraft	74 Percent/interval (yrs)	76 Percent/interval (yrs)	Projected Percent/interval (yrs)
UH-1	22.1/4.5	15.0/6.7	7.9/12.6
OH-58	16.0/6.2	9.3/10.8	0/00
AH-1	18.8/5.3	18.4/5.4	14.8/6.7
CH-47	20.1/5.0	13.3/7.5	4.6/21.7
OH-6	40.8/2.4	12.4/8.1	0/00

CCAD has performed jet engine overhaul and repair. The Army has recently instituted a test program for repair of T-53 engines at CCAD which could significantly reduce the cost of performing depot level maintenance on these engines. Under the test program, only the specific failure which made the engine unserviceable is repaired. This limited repair is costing about $5000 to $6000 per engine versus $11,000 per engine sent to CCAD (for inspection and repair only as necessary) or $22,000 per engine for complete overhaul. In each case, after maintenance, the engine is run on the test stand to ensure it meets Army specifications. Initial results, although limited, indicate that engines receiving only the most limited repair are equally serviceable in the field as engines that get more extensive repair or overhaul. If the test program confirms these initial results, considerable savings will result from the limited repair program. In order to maintain these savings, however, management attention will have to remain focused on preventing more extensive repairs being done. Such a program may prove the feasibility of consolidating repair programs at a depot without incurring the costs often attributed to the tendency to "gold-plate" and make things good as new at the depot. Similar experiments with other components and equipment might also be equally effective and should be encouraged.

V. CONCLUSIONS AND OBSERVATIONS

The DRMS examination of logistics support for Army helicopters confirms that the Army has made great progress toward implementing a much more efficient and effective, combat-oriented support system. Most of the remaining deficiencies we consider important are also recognized by the Army as important, and the Army has taken actions to correct them. In some cases, it would be desirable to move more quickly; however, we recognize that political and funding realities constrain rapid implementation of some proposed changes.

Currently, division AVIMs possess a limited component repair capability. Removing this capability from the divisions and consolidating it with Corps or theater AVIMs appears to offer a number of benefits. It would man and equip the division AVIMs to perform their priority wartime mission of providing contact teams to assist AVUM in the rapid turnaround of combat aircraft through remove-and-replace maintenance. Deleting the component repair capability would eliminate the need for special tools, test equipment, and repair parts, thereby increasing division mobility. The resulting organization would perform in peacetime as it is expected to perform in combat. It would provide a more responsive capability that is better able to meet the commander's needs to weight the battle logistically in a highly dynamic combat environment. In addition, if preliminary calculations are confirmed and are found to be applicable across the Army aviation force structure, the alternative would provide an increase in component repair capability equivalent to adding 160 to 212 repair specialists to existing division AVIM TOEs. This increase would enable a large reduction in the number of components going through the long depot pipeline; additional assets can then be made available to units to support remove-and-replace maintenance at division level and below. Based on factors used in the Depot Roundout Study, 200 maintenance spaces in Europe could result in an additional $43 million worth of assets being available to theater forces. These results indicate the need for and potential benefit to be gained from a more detailed examination of the divisional AVIM component repair mission. The Army is currently reviewing the divisional and nondivisional AVIM TOE structure. This review should be expanded to include a detailed examination of greater consolidation of component repair at Corps and theater AVIMs.

Army supply stockage and distribution policies should be based on expected combat requirements, not on peacetime demands. War Reserve Spare Kits (WRSK) for combat aviation units may increase combat effectiveness significantly, particularly in the early days of a conflict when supply and transportation systems are likely to be disrupted.

Simple and direct means are needed for expediting movement and repair of critical components and for cross-leveling among Army units. Such procedures must be worked out and exercised in peacetime. They should not depend upon computers or extensive communications capability. The Material Management Centers (MMCs) in the divisions, corps, and theater currently provide limited capability and would provide the basis for an expanded capability.

Because transportation in the early days of a European conflict, both inter- and intratheater, would be at a premium, the theater and units in it should be self-sufficient for a time. Current Army doctrine of 75 days of supply of Class IX repair parts should be so implemented as to enable remove-and-replace maintenance at the division level and below. Dedicated intra-theater air and ground transportation to support the proposed alternative, as well as the current maintenance and supply system, need to be evaluated.

The Army should continue its efforts to completely revamp the MACRIT system for developing manpower requirements. A system that relates maintenance manpower requirements to operational mission capabilities will make it possible to distribute manpower and maintenance capability with greater certainty of enhancing mission effectiveness. Many of the factors used to develop aviation maintenance manpower requirements have not been revised or revalidated in a number of years.

Appendix
ARMY AVIATION MAINTENANCE AND SUPPLY SUPPORT SYSTEM

GENERAL BACKGROUND

The Army inventory of 8,800 aircraft includes 8,000 rotary wing aircraft, of which 5,500 are in the active Army and the balance in the Reserve and Guard. Table A-1 shows the inventory by primary mission.

The UH-60A (Blackhawk) and AAH will be entering the inventory over the next few years to improve the troop-lift/assault and antiarmor mission capabilities. Major aircraft modification and conversion programs will affect the CH-47, OH-58, and AH-1 fleets.

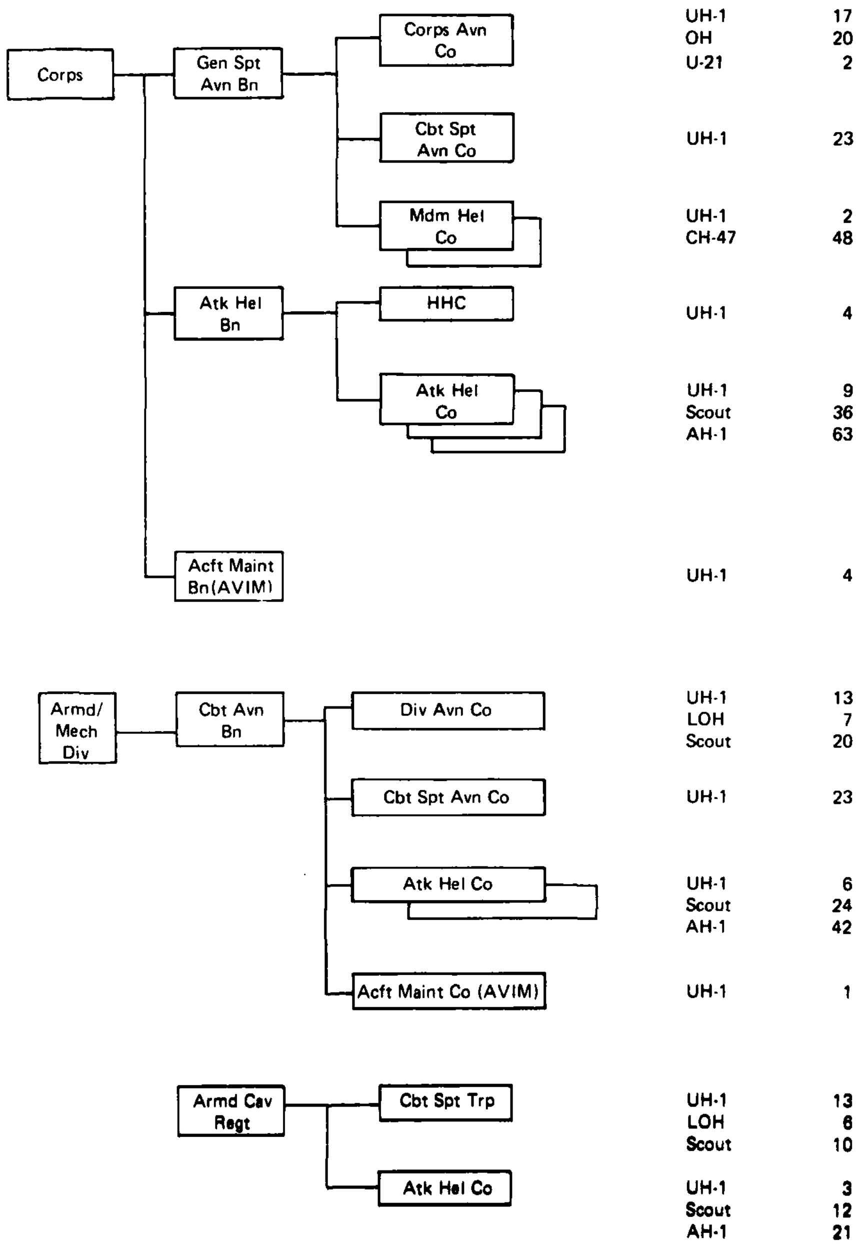
Figure A-1 depicts the helicopter combat force structure for USAREUR Corps, divisions, and Armored Cavalry Regiments, which resulted from the USAREUR Aviation Reorganization Study and the Aviation Requirements for the Combat Structure of the Army III (ARCSA III). Above the Corps would be an additional Aviation Group similar to the Corps General Support Aviation Battalion with 225 rotary wing aircraft. The above structure will add 400 aircraft to the European Theater in peacetime and illustrates the basic elements of the Army aviation structure.

Each aviation company has integral Aviation Unit Maintenance (AVUM) capability. The AVUM performs routine servicing, scheduled inspections and preventive maintenance, fault detection and isolation, and replacement of simple-to-remove parts and assemblies not requiring calibration or alignment, and evacuates unserviceables to an Aviation Intermediate Maintenance (AVIM) unit.

Table A-1.—Army rotary aircraft inventory

Type of aircraft	No. in inventory	Primary mission
AH-1G	406	Attack
AH-1Q	39	Attack (antiarmor)
AH-1S	339	Attack (antiarmor)
CH-47	453	Medium-lift transport
CH-54	73	Heavy-lift transport
OH-6A	414	Observation
OH-58	2033	Observation/scout
UH-1	3948	General utility (troop transport, assault, MEDVAC)

Figure A-1.—USAREUR aviation structure

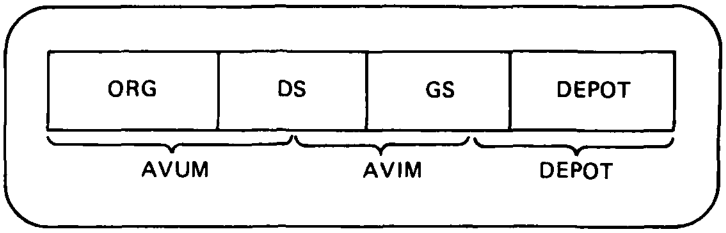


Each division and corps has an Aviation Intermediate Maintenance (AVIM) capability. The AVIM replaces or repairs modules and end items using repair kits, provides direct exchange (DX) and operational float, provides on-site maintenance teams to assist AVUMs, and evacuates unserviceables to the depots. AVIM units are structured according to aircraft density, aircraft type, etc. The division AVIMs, for example, have little component repair capability compared with the corps AVIM. In Europe, the 21st Support Command also has an AVIM with somewhat greater capability than that of the corps AVIMs. Depots perform overhauls, component repair, and other tasks that require more extensive skills, equipment, and facilities than are available in the AVIMs.

Each aviation company maintains a level of supply (Prescribed Load List (PLL)) to support its maintenance activity, and obtains components which are part of a Direct Exchange (DX) program from the AVIM. The AVIM maintains an Authorized Stockage List (ASL) of repair parts, a stock of repaired components for issue through the DX program, and the Operational Readiness Float (ORF) aircraft. To fill their stockage, all AVIMs requisition through the Corps Material Management Center (MMC) on the National Inventory Control Point (NICP) in the CONUS. The CONUS depots fill these requisitions and ship directly to the requisitioning unit via the Air Line of Communication (ALOC).

CURRENT AIRCRAFT MAINTENANCE AND SUPPLY DOCTRINE

Prior to Vietnam, Army aircraft maintenance was organized into four levels of maintenance: Organizational (Org), Direct Support (DS), General Support (GS), and Depot. Experience in SEA pointed up a number of shortcomings in the four levels of maintenance for aircraft. The basic elements required for maintenance at the GS level, i.e., the required number of skilled personnel, facilities, equipment and repair parts, could not be brought into balance. Therefore, the repair of sophisticated components and extensive airframe repair was retrograded to CONUS depots. Repair at the DS and GS level required the duplication of critical resources, including personnel, repair parts and special tools. These resources were spread too thin and shortages resulted. They were subjected to extreme periods of over commitment or non-use. It was felt that greater centralization would provide greater effectiveness and efficiency since skills required for maintenance would not be provided in places where tool shortages, parts shortages, and peaks and valleys in requirements would lead to gross inefficiency, and fewer special tools, shop sets, and test equipment would be needed. As a result the Army began moving toward a three-level concept: Aviation Unit Maintenance (AVUM), Aviation Intermediate Maintenance (AVIM), and depot. The realignment is graphically shown as follows.



This realignment gives the aviation company much more capability to support its own equipment and combines the remainder of the DS and that portion of GS which is readily done in a combat theater. The portion of GS not readily done in a combat theater was realigned to the depot. (One study[1] in 1972 indicated that, for the UH-1D, 77 percent of the functions were to be performed at Org or DS level, 5 percent were GS level, and 18 percent were depot level.) This realignment amounts to the equivalent of at most 200 aircraft maintenance manpower spaces being reallocated from field level to depot level maintenance.

Each aviation company has its own AVUM capability for aircraft maintenance and repair parts supply. The size of the AVUM depends upon aircraft density, type of aircraft assigned, and required Operational Readiness Rates and wartime flying hours. Each division has an AVIM capability in the form of a Transportation Aircraft Maintenance Company to provide aircraft maintenance and supply support to divisional aircraft units. These companies range in size between 107 and 260 depending upon aircraft density, type, and mission. For example, an infantry division with 33 AH-1s, 65 UH-1s, and 62 OH-58s would have a total of 814 people who are either maintenance or supply personnel or personnel assigned to maintenance and supply units. Of the 814 personnel, 625 are assigned to aviation companies and 189 to the division AVIM. Table A-2 shows the distribution of maintenance and supply personnel across the aviation companies' AVUM elements versus the AVIM.

Additional aviation companies with AVUM capability are assigned to Armored Cavalry Regiments (ACRs), Cavalry Brigade (Air Combat) (ACCB), and Corps. Additional AVIM units are located in the Corps and theater support commands. The aviation companies have AVUM capability comparable to that of companies in the divisions. The AVIMs are somewhat larger and have additional component repair capability. Table A-3 compares personnel distributions for five AVIM Tables of Organization and Equipment (TOEs).

Although, conceptually and doctrinally, the nondivisional AVIM is supposed to have more component repair capability than the divisional AVIMs, the above figures

[1] *Army Aircraft Maintenance Structure Study*, U.S. Army Logistics Evaluation Agency, April 1974.

Table A-2.—Distribution of maintenance and supply personnel: AVUMS and AVIM

MOS	AVUMs	AVIM	Total
67 – Aircraft Maintenance[1]	381	59	440
68 – Aircraft Component Repair	96	47	143
35 – Avionics and Armament	78	18	96
– Supply	38	20	58
Total	593	144	737

[1] Includes crew chiefs.

Table A-3.—Personnel distribution for five AVIM TOEs

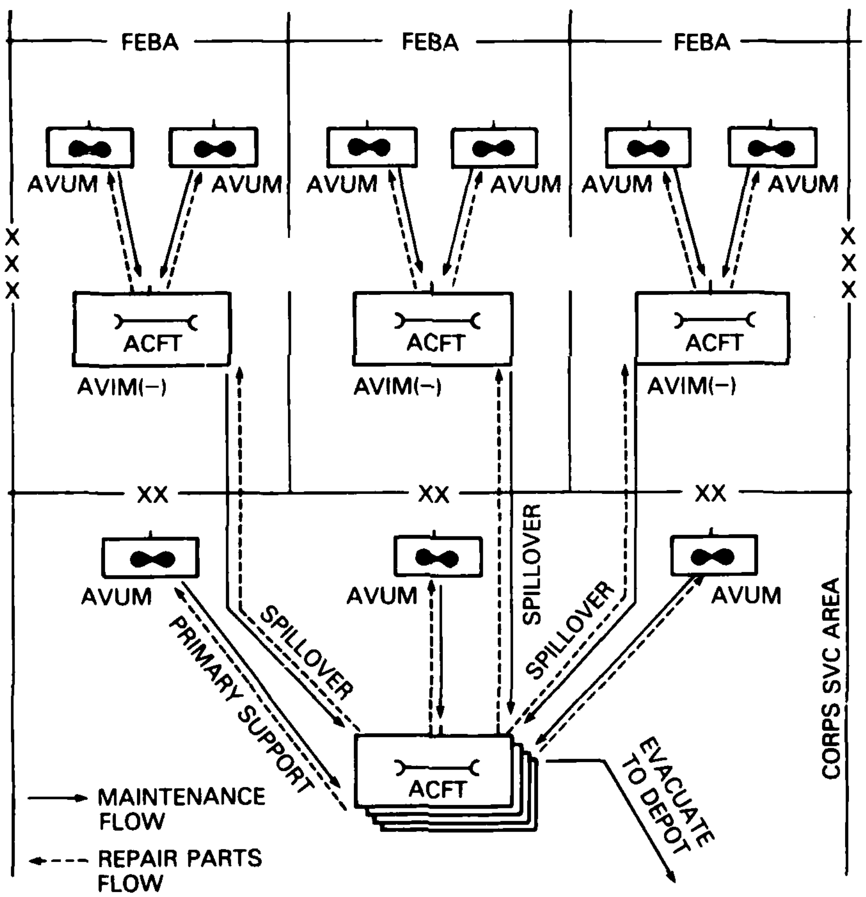
AVIM	*Total* personnel	Aircraft *maintenance* (67)	Aircraft component repair (68)	Avionics & armament (35 & 68J)	Supply
Inf div	163	59	47	18	20
Percent of maint		48	38	14	
Arm/mech inf	107	28	33	15	18
Percent of maint		37	43	20	
Air assault div (2 companies)	520	138	134	100	58
Percent of maint		37	36	27	
ACCB	357	60	152	95	20
Percent of maint		20	50	30	
Nondivisional (Corps/spt cmd)	349	117	96	50	51
Percent of maint		44	37	19	

showing the MOS distribution do not indicate that this is the case. It should be recognized, however, that the "component repair" specialties are also required for on-equipment diagnosis and remove-and-replace actions. Given the typical distribution of aircraft between divisional and nondivisional units, it is not obvious that there is more on-aircraft specialist workload in divisional AVIMs than in nondivisional

AVIMs. These factors would indicate, from a manpower point of view, that nondivisional AVIMs do not have significantly more component repair capability than do divisional AVIMs.

Figure A-2 shows the flow of maintenance requirements to the rear and the flow of repair parts supply and Direct Exchange (DX) parts forward.

Figure A-2.—Maintenance flow chart



Source: Department of the Army Field Manual 1-15, Aviation Reference Data, 30 September 1977, p. 262.

The AVIM company is normally located far enough from the forward edge of the battle area (FEBA) to permit maximum operations within its assigned mission with minimum interruption by enemy actions. The AVIM units repair the aircraft at the user's location whenever possible, using mobile contact teams, to provide maximum available assets to the combat forces.

Each aviation company with AVUM has a limited supply of repair parts and maintenance-related items (Prescribed Load List (PLL)). The PLL varies between units, but generally will be 10 to 15 days of stockage for less than a thousand lines. The AVUM obtains repair parts (secondary items) from the supporting AVIM.

Each AVIM maintains an ASL that is demand-supported and typically includes 5000 to 7000 lines. Replenishment is by requisition through supply channels to the CONUS wholesale system. The AVIM also maintains a stockage of DX items to support the AVUMs in its area of responsibility. Replenishment of DX items is primarily through repair of exchanged items from the AVUM, but may also include additional items requisitioned from CONUS depots.

In Europe, war reserve items are stocked in the GS base in the Support Command and in theater war reserves. (Aviation Class IX war reserves repair parts prepositioned in Europe are presently at 2-percent fill.) Thus, stockage of repair parts occurs at the AVUM, divisional AVIMs, Corps AVIMs, and theater level. Except for theater war reserves, all stockage levels are based on peacetime demand levels and are replenished by requisition through the Corps Material Management Center (MMC), and the theater MMC to the CONUS National Inventory Control Point (NICP). Items are then shipped from CONUS depots to the consolidation point at New Cumberland Army Depot, via air to Europe, and by truck from the aerial port to the requisitioning unit.

Europe was the first to implement three levels of maintenance on a large scale. It also represents the largest peacetime concentration of aircraft outside the CONUS and has been the focus for recent reexaminations of force structure alternatives, operational and support concepts, peacetime versus wartime doctrinal disconnects, and peacetime to wartime transition problems.

Three major changes have taken place in the aviation force structure in Europe. First, attack helicopters have been extracted from the assault helicopter companies, and air cavalry troops (ACT) have been converted to attack helicopter companies (AHC) in order to make more attack helicopters available for antiarmor missions. USAREUR now has two AHCs in each division and one AHC in each Armored Cavalry Regiment (ACR), and an attack helicopter battalion is programmed for each corps. Second, and concurrent with the first action, the aircraft assigned to the Brigade Aviation Sections, Division Artillery Aviation Section, and Division Aviation Company have been combined into a single Division Aviation Company. This results in higher aircraft availability through centralization of assets (assets previously assigned to five different units are now assigned to one) and provide for AVUM support in the unit. Previously, some of the units were too small to warrant full AVUM capability and relied on the Division AVIM company for AVUM and AVIM level support. Third, additional aviation units are being added to the peacetime force structure in Europe. By the end of FY85, these actions will result in the aviation force structure in Europe shown in Fig. A-1.

In addition to the aircraft maintenance and supply personnel at or below corps level, there are maintenance and supply activities at theater level. The 70th Transportation Battalion (AVIM) at Coleman Barracks in the 21st Support Command supports all fixed-wing aircraft and all CH-47s in the theater, plus all other aircraft not supported by a Corps AVIM unit. The 70th's maintenance personnel consist mainly of 200 local national civilians. They support the 60 fixed-wing aircraft in the theater plus 120 rotary-wing. Only about 40 of the rotary-wing aircraft are assigned to units that currently have a full AVUM capability. The 70th is also responsible for receiving and preparing for delivery all aircraft entering the theater and preparing for shipment all aircraft leaving the theater.

A centralized facility at Pirmasens will provide support for all COBRA/TOW armament and fire control systems in Europe. The Airborne TOW USAREUR Repair Facility (A-TURF) was established as an interim capability during the introduction and fielding of the COBRA/TOW into Europe. This facility greatly enlarged the theater capability to isolate and diagnose system interface problems and to repair failed components. In a little over two years the A-TURF was able to repair over 93 percent of the more than 1,000 failed line-replaceable units (LRUs) turned in by COBRA/TOW units.[2] It now appears that the A-TURF capability will be permanently retained in Europe. The MATE (Missile Automated Test Equipment) at Pirmasens will expand this capability with production-model, automated test equipment to support COBRA/TOW assets in Europe.

A study[3] has recently been completed in the Army to augment the depot system using National Guard Transportation Aircraft Repair Shop (TARS) and U.S. Army reserve resources, with some of the capability to be deployed into Europe. The study (Project Depot Roundout for Aviation) proposes forming three Aviation Classification Repair Activity Depots (AVCRADs) that could deploy to Europe and augment the theater aviation maintenance capability upon mobilization. Their mission would be threefold: First, to screen components being returned to the depot and identify those that are being returned unnecessarily, such as assets that are still serviceable or require only minor repair. (About 15 to 20 percent of the assets returned to the depot either have not failed or are field-reparable.) Second, return serviceable assets to theater stocks. Third, provide a somewhat greater capability for repair of assets than exists in the AVIMs, in order to repair as many assets in-theater as possible. The result would be to reduce the supply pipeline and maintain a larger in-theater stockage of serviceable assets.

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[2] Hq USAR LTR, Subject: Project Maximize Initial Findings, dated 24 April 1978, Enclosure 9, p. 9.

[3] Project Depot Roundout for Aviation, U.S. Army Materiel Development and Readiness Command (DARCOM), dated July 1978.

LOGISTICS SUPPORT ALTERNATIVES FOR ARMY TRACKED COMBAT VEHICLES

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FIGURES

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I. INTRODUCTION

The U.S. Army is continuing the trend toward increasing mechanization of its forces which began several years go. The number of armored and mechanized divisions has increased, along with the number and sophistication of mechanized weapons per division. This trend is expected to continue for the next several years and will place an increasing burden on the logistics support system. This case study examines the theater logistics support structure for tracked combat vehicles and suggests a number of changes which warrant further evaluation.

The Army operates and maintains a fleet of over 30,000 tracked combat vehicles, including tanks, armored personnel carriers (APCs), self-propelled artillery, and tracked recovery vehicles. Army Field Manual FM 100-5, *Operations*, states that "the tank, with its cross-country mobility, its protective armor, and its formidable firepower, has been, and is likely to remain, the single most important weapon for fighting the land battle."[1] The APC increases infantry mobility by 2-1/2 times over footborne infantry, provides armor protection and, when equipped with antitank missiles and automatic weapons, constitutes a substantial firepower delivery system.[2] As pointed out in FM 100-5, by the mid-1970s, one out of every two infantrymen in the active U.S. Army was a member of an APC mounted force.[3] Self-propelled artillery in armored and mechanized divisions is able to move with armored forces or displace laterally to concentrate fire quickly where needed. Self-propelled air-defense artillery is able to move with the other mechanized elements to counter the airborne threat.

The Army is engaged in the most extensive peacetime modernization program in its history. New procurement (M60A3 and MX1 tanks), modernization of existing equipment (M60 tanks and M113 personnel carriers), and phaseout of old equipment (M551 cavalry vehicle) will affect a large portion of the tracked combat vehicle force over the next few years. General William E. DePuy, USA, Retired, states that "one of the most significant challenges faced by today's military forces is how to exploit fully the combat power provided by high technology weapons and equipment."[4] This challenge is nowhere greater than the one confronting the logistics structure, which must insure that combat-ready weapons are available when and where needed.

The challenges of supporting more sophisticated weapons, in a combat environment different from previous experience, in a resource-constrained environment where combat forces are likely to be outnumbered, will place increased stress on the logistics structure and demand that it be more flexible and responsive than ever before. This study is an attempt to understand the magnitude of these factors, their potential impact on logistics support, how the Army is moving to meet these challenges,

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[1] Manual 100-5, *Operations*, with changes, 29 April 1977, p. 2-6.
[2] Ibid., p. 2-11.
[3] Ibid., p. 2-10.
[4] *Armor*, September 1978, p. 22.

logistics structure and demand that it be more flexible and responsive than ever before. This study is an attempt to understand the magnitude of these factors, their potential impact on logistics support, how the Army is moving to meet these challenges, and whether additional changes would lead to more effective and efficient logistics support.

Because this report does not present the results of completed research, it does not recommend courses of action for implementation. The complex interrelationships among combat units and logistics support forces do not permit rational extension of these results beyond indicating whether or not the Army appears to be proceeding in the proper direction and identifying areas that warrant further consideration. Prior to any implementation, these ideas must be subjected to additional analysis and testing.

Section II discusses the principal factors affecting the logistics structure required to support weapon systems in combat, how these factors are changing, and how they influence demands on the logistics system. Section III describes the current Army logistics concepts and structures and how they are evolving to meet changing demands. Section IV, "Logistics Structure for Tactical Combat Forces," is organized in three parts. The first part discusses the six principles that form the basis for the recently approved Army Logistics Concepts for use in Policy, Doctrine, Planning and Training, and presents our supporting views. The second part presents a somewhat different approach to analyzing the maintenance function, and discusses the feasibility of realigning the functions to provide more effective support to combat forces. Finally, a conceptual alternative to the current Army maintenance and maintenance supply system is discussed. Section V discusses a number of other issues and observations, while Section VI presents our conclusions. The appendix provides a somewhat more detailed description of the Army maintenance and supply system using an armored division for illustrative purposes.

II. BACKGROUND

Many factors influence the logistics structure required to support combat forces, including the number and characteristics of the weapons possessed by these forces, how they are to be used, the characteristics of the combat environment, and the level of resources available. This section discusses these factors, how they are changing, and how they may affect demands on the logistics system.

The armored and mechanized divisions of the Army are heavily equipment-intensive. This case study focuses only on one class of equipment, vehicles, and only on tracked combat vehicles within this class. The *U.S. Army Armor Reference Data*, ST-17-1-1, indicates that a typical armored or mechanized infantry division would have on the order of 5500 trucks, trailers, and tracked vehicles. Roughly 1500 of these are tanks, APCs and self-propelled artillery.[5] Many of these vehicles are equipped with sophisticated communications equipment, fire control computers, laser range-finders, and sophisticated propulsion and power-train systems. New equipment being procured for the combat forces is even more sophisticated and will require even more sophisticated test equipment and skilled maintenance personnel if their full combat potential is to be realized.

Mechanized forces are intended to be highly mobile and able to react to rapidly changing requirements on the battlefield. They must be able to operate in rough terrain in small, fast-moving units and be capable of massing to provide concentrated firepower. The limited number of specialized weapon systems available to small units requires that the maximum number of weapons be constantly combat-ready, or the unit's total capability will be seriously degraded. This means that the logistics forces must also be highly flexible and responsive to changing requirements on the battlefield and be capable of supporting the small isolated unit as well as large concentrations of equipment. They must be able to return damaged equipment to combat as quickly as possible.

The Army must be prepared to fight successfully, anywhere in the world, in any type of environment. Some scenarios are more likely than others, and some are more demanding. FM 100-5, *Operations*, points out that, "Battle in Central Europe against forces of the Warsaw Pact is the most demanding mission the U.S. Army could be assigned."[6] FM 100-5 further indicates that the U.S. Army must be prepared to face a scenario where the enemy possesses weapons generally as effective as our own; where he will have those weapons in greater number than ours, at least initially; where very high losses can be expected in short periods of time; and where the first battle could be the decisive battle.[7]

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[5] *U.S. Army Armor Reference Data*, ST 17-1-1, Vol. I, U.S. Army Armor School, Fort Knox, Kentucky, FY 1977.

[6] Ibid., 100-5, pp. 1-2 and 3-1.

[7] Ibid., p. 1-1.

These and other views portend a scenario that will tax combat and support forces alike. The transition from peace to war will be hectic. During the initial period, armored thrusts will attempt breakthroughs to be exploited by highly maneuverable mechanized forces. Combat will be intense, pressure will be unrelenting day and night, and attrition will be very high. Combat units will need high mobility to blunt initial attacks, reinforce battered units, and reallocate scarce resources to points of greatest need. NATO forces will be outnumbered, at least initially, and will have to react quickly to concentrate combat capability at the points of greatest need. After the initial phase, the front will become more stable and units will have to be reconstituted and supported for a period of sustained combat. These factors again indicate a need for logistics readiness, mobility, flexibility and responsiveness greater than ever before. The traditional system, designed to execute prior-planned operations where we have the initiative and superior resources, a situation more typical of the past, is unlikely to possess the qualities required for a NATO/Warsaw Pact conflict of the kind described above.

The level of resources available is a significant factor in whether or not a logistics system can provide adequate support. Almost any system can do so, no matter how inefficient, if unlimited resources are available. On the other hand, no system can provide effective support if the level of resources is too low. Between these two extremes are many combinations of people, equipment, repair parts, and other resources, and many ways of organizing them that will be more or less effective and efficient depending upon the total amount of resources available. For the foreseeable future, it is unlikely that sufficient resources will be available to simultaneously satisfy all possible contingencies. Even if they are, it is unlikely that enough resources of every type would always be available to every unit when required in the European scenario envisaged. The likely situation in that environment might be described as one of allocating shortages where they will do the least harm. This requires a resource management system that tries to anticipate demands, allocate and reallocate resources quickly as the needs develop, and exert almost instantaneous control over the total resources available to weight the battle logistically.

These factors have been exacerbated to an unknown extent by changes in the logistics structure over the past few years, occasioned by extreme pressures for peacetime efficiency. During a time when combat forces have been increased and mechanization of combat forces with more sopisticated equipment has increased, support forces and support management levels have been decreased. For example, in Europe the number of combat units has increased, the number of logistics support units has decreased, CONUS and overseas depots have been closed, almost total reliance has been placed on the CONUS wholesale structure (vis-a-vis in-theater capability) for repair parts and other supplies, and much greater reliance is placed on Reserve Component logistics units to provide required wartime logistics support. The average grade and experience levels in logistics units have decreased while training courses for new personnel have been shortened. All of these actions were driven to a great extent by the need for peacetime economies. In some cases they may have been taken with less than adequate attention to their effect on combat capability. In any case, they have certainly increased the stress on the logistics system and the need to seek the most efficient and effective combat logistics structure.

III. CURRENT AND EVOLVING ARMY LOGISTICS

Maintenance and repair parts supply support are critical elements in the logistics system. Given the changing environment discussed above, it would seem reasonable that these changes would be reflected in the Army's concepts and structures for providing maintenance and supply support to tracked combat vehicles. This section describes these basic concepts and structures, how the Army sees them evolving over the next few years, and other initiatives and studies that could affect Army logistics in the near future.

The basic Army philosophy is that maintenance is a command responsibility and should be performed at the lowest level practicable.[8] There are four categories of maintenance. (1) Organizational maintenance is performed by the crew/operator and by mechanics assigned to units possessing the equipment. The crew/operator is responsible for preventive maintenance such as checking, cleaning, lubricating, and adjusting. The mechanics in the company and battalion inspect, replace some minor components/assemblies, replace piece parts, and evacuate unserviceables. (2) Direct support maintenance includes diagnosis of malfunctions, repair, replacing components/assemblies, armament repair, and exchange of parts with the supported battalion. (3) General support maintenance includes heavy-body, hull, turret, and frame repair; repair and limited overhaul of end items and components/assemblies; and backup support to the divisions. (4) The depots provide overhaul of end items and components and perform repair that is beyond the capability of General Support maintenance. Repair parts follow the same general maintenance channels. (A more detailed discussion of the maintenance and supply system is contained in the appendix.)

Figure 1, extracted from an Army briefing, shows the Army maintenance system as it would be arrayed on the battlefield.

A number of studies have been recently completed or are under way within the Army which address specific shortcomings in the current logistics posture. These studies affect virtually every echelon and category of maintenance and supply support for tracked combat vehicles.

The Division Restructuring Study (DRS) is examining an alternative company/battalion structure for the armored and mechanized division in an attempt to more fully exploit the combat power of new weapons and equipment. The major elements include: (1) reducing the size of each company and equipping it with a single weapon system, based on its mission to engage the enemy with tanks, infantry, or antitank guided missiles; (2) shifting the task of coordinating the combined arms from the company to battalion level; and (3) changing the combat support and service support system in line with the new concept. All of these elements are intended to reduce and simplify the technical, tactical, and training responsibilities at the lower echelons.

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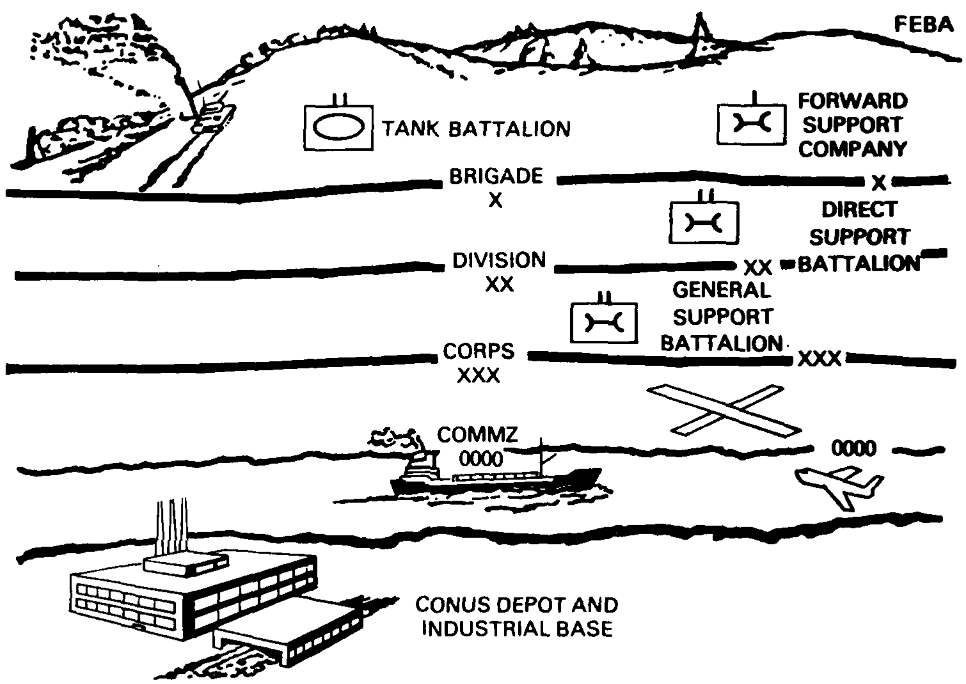
[8] Department of the Army, Field Manual 29-2, *Organizational Maintenance Operations*, August 1975, p. 3-1.

Figure 1. The Army maintenance system



DRS would centralize all organizational mechanics at battalion level rather than having them distributed over the five companies as in the present system. The DRS evaluation at Fort Hood also embodies the concept of Consolidation of Administration at Battalion Level (CABL).

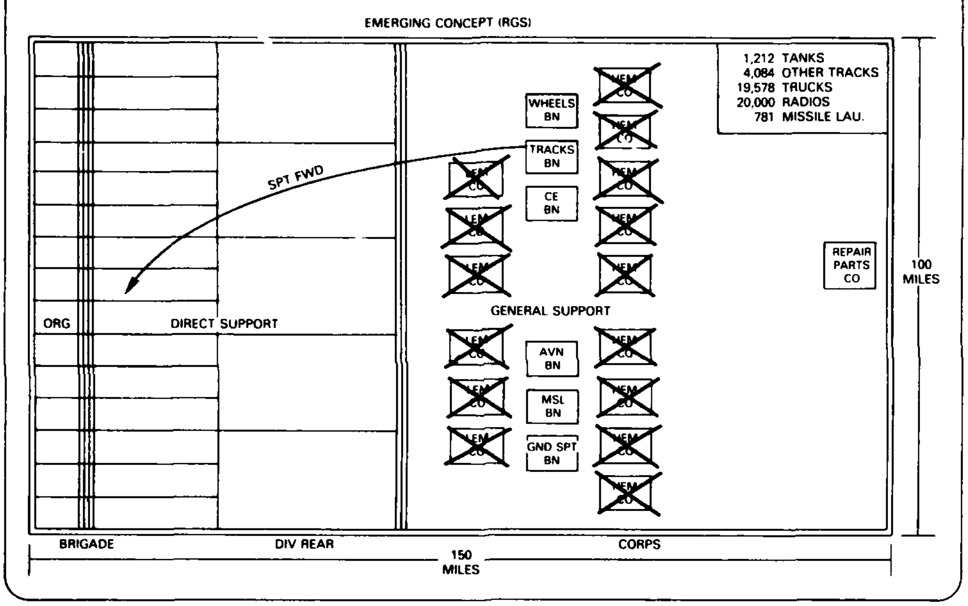
CABL provides for the elevation to battalion level of all formal administrative and logistics functions normally performed at company level. These include personnel administration, food service, training management, supply, and maintenance. Objectives stated in DA Pamphlet 1-2 are to reduce the time devoted to these functions by the unit commander and first sergeant; improve unit training, readiness and leadership; standardize and simplify procedures; improve support to the soldier; and develop skills of personnel through concentration of tasks, crosstraining, and experienced supervision.[9] Consolidation of Personnel administration has been implemented. Imple-

[9] Department of the Army, Pamphlet 1-2, *Administrative and Logistics Handbook; Guide for Battalion and Company Level Administrative and Logistic Procedures*, October 1977, p. 1-2.

mentation of the remaining CABL functions was initially permissive but has been subsequently halted.

The Army is also evaluating a concept for Restructured General Support (RGS), which would replace the current multifunctional/area orientation of the Corps GS units with a commodity and weapon system orientation. The mission of the Corps GS would also be oriented more toward support forward and support to the user, rather than the traditional repair in support of the supply system. Figure 2, extracted from an Army briefing, depicts the emerging RGS concept.

Figure 2. Restructured General Support (RGS).



The Army recently approved a set of Logistics Concepts for use in Policy, Doctrine, Planning and Training as a result of the Phase II study, Logistics Operations in the Communications Zone. The Phase II Study addressed the problem of voids in logistics concepts, policy, doctrine, and planning for supply, maintenance, and transportation support of the U.S. Army in a NATO environment, involving the logistics organizations and systems in the COMMZ, i.e., the area in the theater behind the Corps rear boundary. It recommended a reorientation of the corps general support mission to one of support of the user rather than support of the supply system, and creation of a logistics capability in the communications zone to support the supply system and interface with the CONUS wholesale structure. A total of 21 concepts recommended by the Phase II study were approved.[10]

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[10] Office of the Deputy Chief of Staff for Logistics, *Logistics Concepts for Use in Policy, Doctrine, Planning, Training*, June 1978.

The Army also has under review and study a plan to reorganize the Mechanical Maintenance Career Management Field (CMF63), which includes all tracked combat vehicle mechanics and repairmen. Under the proposed reorganization, direct support and general support (DS/GS) maintenance remains with commodity-oriented repairmen specialized in tracked or wheeled vehicles, armament, or machinery. At the organizational level, automotive and turret mechanics will be trained to maintain one specific major combat vehicle or family of vehicles. The organizational mechanics would progress through five levels of skill. At skill level 4, the "master mechanics" would be fully cross-trained on all track and turret components of the vehicle they are trained to repair. The restructuring is intended to increase the expertise and capability available at the organizational level to meet the perceived demands of the combat environment. Each master mechanic would be fully qualified on all elements of a single weapon system, rather than on a single area of a family of weapon systems.

Through these and other studies, the Army has identified a number of shortcomings and taken action to correct them. The tenor of these actions is captured in six principles that form the basis for the currently approved 21 Army Logistics Concepts mentioned earlier:

1. Reducing the logistics burden on the combat forces in the forward combat areas.
2. Fixing combat-essential weapon systems as far forward as possible to maximize their contribution to the battle effort.
3. Consolidating application of logistics resources behind the forward battle area wherever possible to capitalize on economies of scale and maximize the use of critical skills, tools, and test equipment.
4. Assuring that logistics resources in the theater are fully responsive to the needs of the theater commander.
5. Reducing to a minimum the theater commanders' initial dependence on CONUS depot support by increasing theater war reserve stocks and ammunition consistent with their combat needs and management capability. And further reducing initial dependence on CONUS support by increasing combat-essential spares with theater forces, emphasizing components and "black boxes."
6. Reserving limited theater transportation resources for critical resupply and evacuation of reparable assets beyond their capability to handle in the forward area.[11]

These principles reflect most of the qualities essential for effective logistics support to tactical forces. They typify the direction in which both the Army and Air Force appear to be moving to respond to a mid- to high-intensity tactical combat environment where our resources are likely to be strained to the limit. The next section articulates why DRMS supports these principles and the need for actions to fully reflect them in logistics organizations and systems.

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[11] Memorandum for Study Director, Resource Management Study, from Director of the Army Staff, 19 July 1978.

IV. LOGISTICS STRUCTURE FOR TACTICAL COMBAT FORCES

The first part of this section discusses, from the DRMS viewpoint, the six principles that were listed at the end of the preceding section. The second part presents a somewhat different approach to analyzing maintenance functions and discusses the feasibility of realigning the functions to provide more effective support to combat forces. Finally, a conceptual alternative to the current Army maintenance and supply system is discussed.

PRINCIPLES FOR TACTICAL COMBAT LOGISTICS ORGANIZATION

Reducing the logistics burden on forward combat units should enhance combat effectiveness, resource management effectiveness, and efficiency. It will heighten the units' mobility and flexibility and their integrated logistics capability. The combat unit will no longer have as heavy a burden of moving large quantities of specialized equipment, repair parts, and personnel, which often require facilities for effective use that are not always available in a forward combat area. Resource management effectiveness is increased by reducing the amount and kinds of resources that the combat unit commander must manage. Management of combat resources—personnel, material, and the logistics required to support them—has always been complex and is growing more so. Resource constraints will continue to force tough tactical decisions. It will benefit the combat unit commander to focus his attention primarily on immediate mission-essential factors. Increased combat efficiency results from better utilization of personnel and equipment and a consistent unit goal of generating immediate combat capability. Simplification of training, supervision, and management tasks will produce more efficient organizational structures tied to a single mission focus.

The Army principle of *fixing weapon systems as far forward as possible* increases their combat availability. Evacuating an entire weapon to the rear for repair, instead of its failed component, reduces weapon availability in two ways. First, it is unavailable during the time it takes to obtain very limited specialized transportation equipment and move the weapon to the rear and back after repair. Second, repair in the rear may take much longer than it would in the operating organization, which is likely to have a greater sense of urgency. When it is possible to repair forward, it is quicker to transport the required component and a repair team, if required, rather than transport the weapon system, repair it in the rear, and then return it to the user.

Consolidation of logistics resources behind the forward battle area not only relieves the burden on the combat commander, but also makes economies of scale possible. In many cases, specialized skills, tools, and test equipment would be underutilized if placed with each forward combat unit, since no one unit would generate enough workload to keep them busy all the time, even at peak demand. Even if they are fully utilized at peak demand, peak demands are unlikely to occur simultaneously in all units. Therefore, consolidation across units tends to smooth the total demand

and uses scarce resources more efficiently. Consolidation behind the forward battle area increases the opportunity to use more productive fixed or semifixed facilities. Maintenance would not be disrupted by the combat environment and the frequent need to move. (Army planning factors in AR 570-2,[12] for example, increase man-hour availability by almost 25 percent when facilities are fixed.) Consolidation in the rear area is also more conducive to a production-line capability, which would be virtually impossible in the forward area, and may open up possibilities for using special technology that would otherwise not be practicable. Complex test and repair equipment that requires fixed facilities with a controlled environment may be much more productive in the rear and infeasible elsewhere. These latter considerations become more and more important as the sophistication of Army equipment increases.

It is vital that *in-theater logistics resources be fully responsive to the needs of the theater commander.* Priorities are likely to change rapidly in the early stages of a war, and organizations outside the theater will be less able to adequately respond to changing needs. It takes time to communicate changing requirements through multiple levels of command, and more time to communicate changing priorities back down to effect theater resources distribution. Because no one above the theater commander is likely to have additional information that would permit a "better" decision, he should have the authority and the means for reallocating resources already in the theater as well as those committed but not yet in-theater. The means must include a logistics command, control, and resource management system.

The theater must depend on its own resources during the initial phase of hostilities. The transition from peace to war will be hectic, transportation resources will be taxed, and lines of communications subject to disruption. Sufficient supplies must therefore be on hand at the outset, along with the means to distribute them efficiently. Combat-essential spares should consist of components and black boxes to emphasize a remove-and-replace maintenance concept at the front to maximize weapon availability. A deadlined piece of equipment is merely a target until it can be repaired and returned to combat. Remove and replace is always faster, simpler, and usually more effective than remove, repair, and replace.

Limited theater transportation resources should be reserved to move reparable assets which cannot be repaired in the forward area in order to assure maximum weapon system availability.

These six principles embody the characteristics required for an effective logistics support capability. They exemplify the thrust of many on-going Army programs to increase the capability of the logistics system to respond to wartime demands.

MAINTENANCE FOR TRACKED COMBAT VEHICLES

This section divides maintenance of combat vehicles into two main categories and discusses the feasibility and potential advantages of structuring maintenance organizations to respond to the somewhat different demands of these two categories.

[12] Army Regulation 570-2, *Organization and Equipment Authorization Tables—Personnel,* with changes, 22 July 1969, p. 2-3.

In wartime, the priority mission of all logistics elements will be to return failed weapon systems to combat as quickly as possible. This is the premise upon which fix-forward is based: Fix-forward envisions that on-equipment maintenance, i.e., repair that requires the weapon system to be available for the repair to take place, will be done as far forward and in as expeditious a manner as possible. Only if the repair is going to take an extended period of time—major damage to the vehicle body, hull, turret, etc.—will the weapon be evacuated to the rear. As discussed earlier, this is certainly the most effective means of maximizing the number of weapons that are combat-ready at any given time. Off-equipment maintenance, i.e., component repair that can be done after the component is removed from the weapon, does not require the weapon system to be present and should be geared to ensuring that repaired components are available when required to support forward on-equipment maintenance. The location where off-equipment work is performed, geographically and organizationally, also affects the effectiveness and efficiency of the logistics system.

The current system plans a mix of on-equipment and off-equipment maintenance at every level except the organizational level. A sharper differentiation between on-equipment and off-equipment maintenance, and a sharper focus organizationally, might provide a more effective and efficient logistics system. An extreme example might be to man a first echelon to perform all on-equipment work. This echelon would operate in the forward combat area and would depend on a source of supply for components, assemblies, and repair parts required to perform the most expeditious repair of the weapon system possible. A second echelon, located to the rear of the combat area, would repair failed components and assemblies for return to the first echelon. This would allow for specialization, a focused mission, etc. Such an extreme is unlikely to be very efficient or very effective because of transportation costs, costs for spare components and assemblies to fill the pipeline, and the like. Many studies, such as the Tank Weapon System Management Study and the Phase II Study, have suggested that some movement in this direction, however, would be beneficial. Our review supports these findings.

The importance of rapid repair turnaround in the forward area, as reflected in current and evolving Army doctrine, versus evacuation of the end item for repair to the rear is dictated by the relative time and cost of each. Figure 3 shows the sensitivity of turnaround time to its major components.

The data in Figure 3 were derived from results of the Maintenance Support Concepts (MASC) Model runs used by the Army to evaluate the Restructured General Support (RGS) concept.[13] Almost half of the turnaround time consists of either waiting for transportation or actual transportation time. Waiting for parts is the second largest element. Figure 3 indicates the importance of being able to perform on-equipment repair forward, and the importance of having repair parts avalable where and when needed to effect the repair.

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[13] U. S. Army Logistics Center, *Maintenance Support Concepts (MASC) Simulation of Restructured General Support (RGS), Final Report*, July 1978.

Figure 3. Turnaround time sensitivities

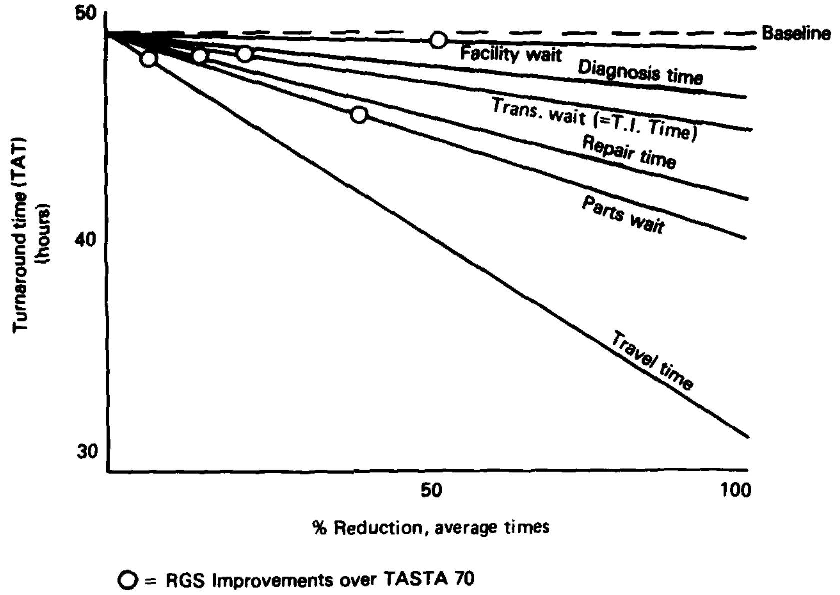
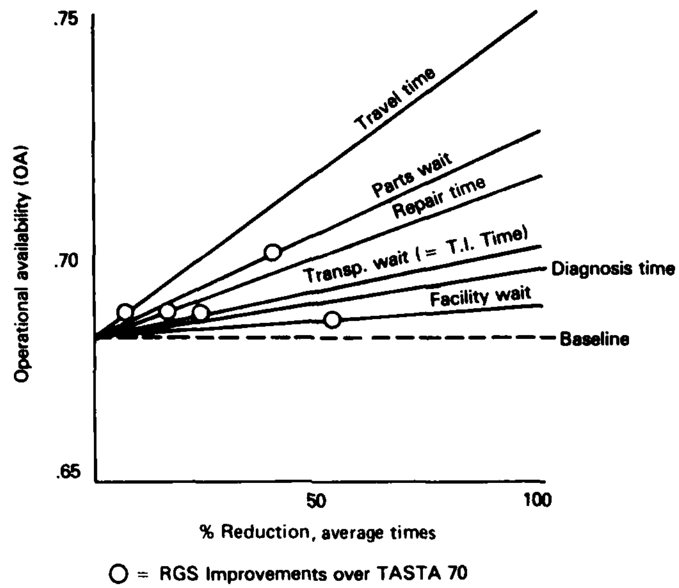


Figure 4 shows the same elements relative to their effect on operational availability. (The improvements estimated for RGS over the current structure are indicated by "0" in Figs. 3 and 4.)

These data indicate that to make a significant improvement in weapon availability, emphasis should be on having parts and personnel organized to effect a fix-forward philosophy. This would reduce the large proportion (almost 2/3) of the nonavailable time for weapon systems currently spent awaiting transport, being transported, or awaiting parts. In recognition of these factors, the Army in RGS, Phase II and other studies has been seeking organizational structures and procedures to increase their capability to fix forward. The MASC evaluation indicates that the RGS, which affects only Corps GS units, would improve operational availability by about 10 percent. Organizational and procedural changes that are geared to specifically reducing the major causes of delay, by improving the capability to mass on-equipment repair capability forward with the required repair parts needed for rapid turnaround of weapon systems, would presumably make even more significant improvements.

Figure 4. Operational availability sensitivities



One way of massing more capability forward would be to simply increase the number of mechanics in each combat company and the amount of repair parts in each maneuver battalion. While this would likely be effective, it is also likely to be very costly because of the need for manning each company to take care of peaks in wartime demands. The opposite extreme would be to pool all on-equipment capability for command and control purposes and allocate them to individual units as the demands occurred. This would take advantage of smoothed workload, but would likely present an unmanageable command and control problem. What is required is a distribution of resources that balances effectiveness and cost in a reasonable way. For on-equipment work it would be desirable to err on the side of providing some excess capability at each level in order to assure rapid turnaround of costly and valuable weapon systems. The cost then will depend upon how much workload varies between units, how much peaking occurs simultaneously in multiple units, how well the command and control system can reallocate resources in the midst of combat, and the responsiveness and adequacy of transportation resources.

Having mechanics postured to support forward, however, solves only part of the problem. As noted in Figs. 3 and 4, waiting for repair parts accounts for a significant part (on the order of 20 percent) of the nonoperational availability of current systems. Relying on quick-fix repairs involving more reliance on replacement of components forward generates an even more urgent need to have adequate components and assemblies available in the forward area. The Tank Study, Phase II and other studies have identified advantages in posturing the logistics system so that repair of components/assemblies is accomplished to the rear to the maximum extent practicable. The question left unanswered is: What is the maximum extent practicable? How many components can be replaced at the front and repaired in the rear, and how long does it take to replace them versus repairing them without removal? What would it cost to buy enough components to permit them to be shipped to the rear, repaired, and shipped back to the front considering transportation time and delays? These and other questions are amenable to quantitative analysis.

First, the question of feasibility. An important factor in determining whether a sharper differentiation between on-equipment and off-equipment maintenance would be more effective is the extent to which components can be removed and replaced and repaired elsewhere in time and place, versus the need and comparative repair time and cost for repairing the end item itself using bit and piece repair parts. A review of existing Maintenance Allocation Charts (MAC) shows a wide range of potential. Table 1 illustrates this range with extracts from the M60A1E3 MAC.[14] In the first example, it takes 0.3 man-hours to repair the Filter Assembly Fuel/Water Separator on the tank, compared with 9 man-hours to replace it. In such cases it would clearly not be advantageous to go to a remove-and-replace concept. Based on time alone, it also would not make sense to replace the Power Plant Wiring Harness at DS level (3 man-hours) if it can be repaired at organizational level in one man-hour. In such cases, however, it might be useful to analyze the quality of the two types of repair actions. For example, if a repaired harness, on the average, has a mean time to failure that is less than one-third that for a replaced one, then, based only on total repair time, it would be advantageous to remove and replace on failure. (Of course the ultimate decision will depend on factors other than minimizing equipment downtime, such as storage costs, transportation costs, etc.) The third example, transmission, is one where the system should seek to assure that a transmission is available to replace a broken transmission in 20 man-hours rather than requiring a total of 70 man-hours to remove, repair, and replace, with the tank deadlined all the while.

The fourth example is one that is becoming more common as newer, more sophisticated, and modular equipment is introduced into the inventory. Except for very simple repairs such as replacement of knobs and fuses, components like the M13A3 Fire Control Quadrant are replaced upon failure at the organizational level, evacuated to DS for repair and, if the repair is beyond the capability of the DS level, are evacuated to the depot for overhaul. In these cases it may be advantageous to centralize the component repair function above the DS level and, taking advantage of economies of

[14] *Logistics Support Plan, Tank, Combat, Full-Tracked 105mm Gun, M60A1E3*, February 1977, U.S. Army Tank-Automotive Material Readiness Command.

Table 1.—M60A1E3 MAC

Component/ assembly	Maintenance function	Crew/ operator	Maintenance category: ORG	DS	GS	Depot
Filter Assembly Fuel/water Separator	Inspect		1.0			
	Service		.4			
	Replace		9.0			
	Repair		.3			
Harness, Wiring Power Plant	Inspect		.3			
	Test		.3			
	Replace			3.0		
	Repair		1.0			
Transmission	Inspect		.3			
	Test		.3			
	Service	.3				
	Adjust		3.5			
	Replace			20.0		
	Repair			50.0		
	Overhaul					94.0

scale inherent in fewer repair points, also perform the depot repair/overhaul function at the same place. Effectively, this lengthens somewhat the transportation time in moving the item past the DS level but shortens the depot pipeline loop. (The Army Project Depot Roundout for Aviation Study identified a 95-day reduction in pipeline time for aviation items repaired in theater, as compared with returning them to

CONUS depots for repair.)[15] Depending upon the proportion normally returned to the depot, the reduction in depot pipeline requirements can more than compensate for increased in-theater pipeline and result in greater component availability to the combat forces.

One measure of the feasibility of decentralizing selected on-equipment work and centralizing off-equipment and more extensive on-equipment work is provided by an examination of data developed from FM 42-9-1, *Maintenance and Repair Parts Consumption Planning Guide for Contingency Operations*. This manual contains logistics planning information for the M60A1 Tank for a 120-day Middle East scenario. The Contingency Maintenance Allocation Chart (CMAC) contained in the manual identifies recommended reallocations of maintenance tasks and maintenance tasks which may be performed at a lower level of maintenance if authorization is granted. Table 2 shows three examples of items coded in the CMAC for either recommended reallocation to a lower level (denoted by *) or for performance at a lower level if authorization is granted (denoted by %%). The examples shown are all remove-and-replace actions moved from DS level to the organizational level. The CMAC includes other types of tasks recommended for movement downward from GS to DS, DS to ORG, DS to Crew/Operator, and ORG to Crew/Operator. In terms of number of items and man-hours, most downward reallocations involved movement of replacement tasks from ORG to Crew and DS to ORG. Table 3 shows examples of repair tasks recommended for reallocation upward from DS to GS. Again, there were reallocations affecting other levels, but the largest allocations upward in terms of number of items and total man-hours were from DS to GS. Figure 5 shows the total man-hours recommended for reallocation from the DS level either upward or downward. Note that of the total workload originally coded for DS level, almost 70 percent is coded for reallocation in the M60A1 CMAC.

Figure 6 shows the net impact of all reallocations contained in the CMAC for the M60A1 Tank. Analysis of the CMAC data for the M60A1 indicates that opportunities do exist for decentralizing on-equipment and centralizing off-equipment work to a greater extent than is reflected in current organizations and manning.

As discussed earlier, the decentralization of on-equipment work would move that work closer to the point of failure and increase operational availability by reducing the number of items evacuated, requests and waiting time for specialized transportation assets, and transportation time and/or waiting time for contact teams to move to the point of need. The impact of transportation times on turnaround and operational availability, discussed earlier, illustrates the need for more responsive on-equipment capability. The CMAC data indicates considerable potential for reallocating more on-equipment workload downward and more off-equipment workload upward. The questions remaining include: What are the costs involved in reflecting such reallocations in the logistics organizational structure, and what ultimate effect would such changes have on combat capability? While considerably more quantitative analysis of empirical data is required to estimate the potential costs with any degree of accuracy, a number of statements can be made as to the likely directions of change.

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[15] U. S. Army DARCOM, *Project Depot Roundout for Aviation*, July 1978.

Table 2.—Examples from M60A1 CMAC

Component/ assembly	Maintenance function	Maintenance category ORG	DS	GS	Depot
Pump injection Fuel	Replace	*	10.0		
	Repair				
Transmission Assembly	Replace	%%	16.5		
	Repair			80.0	
Nozzle, fuel Injector	Replace	*	3.5		
	Replace			1.3	

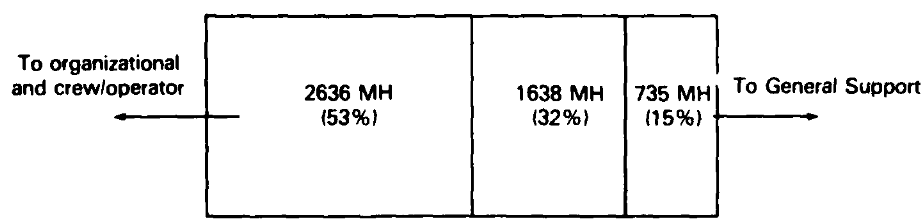
Decentralizing maintenance capability could be expected to increase the requirements for mechanics, tools, and test equipment, and decrease the requirement for spares and transportation. This, to a large extent, is dependent on four workload characteristics: the average workload generated in a unit; how drastically the workload changes over time in the units, i.e., the difference between average workload and peak workload; the degree of variability in workload over time between units, i.e., to what extent do workloads peak at the same time in different units; and the degree of responsiveness required, i.e., how long a unit can wait for a contact team before combat mission capability is adversely affected.

The average workload dictates the number of maintenance personnel who can be fully utilized over time. If this number is very small for a particular skill, it may be impossible to maintain a sufficiently skilled work force. For example, each armored cavalry troop is authorized two tank turret mechanics. The presumption is that two skilled tank turret mechanics are available to each company. In reality this is often not the case. Sometimes the mechanics are inexperienced and less than fully skilled, or perhaps one is inexperienced and the other is less than fully skilled. The lower the density of mechanics, the greater the effect of small changes in numbers or degree of skill of people actually assigned to the unit. In such cases consolidation at a higher level may produce more robust, responsive, and capable maintenance organizations. This, to some extent, seems to be part of the rationale behind the DRS proposal to consolidate organizational mechanics at battalion level rather than having them distributed among the companies.

Table 3.—Examples from M60A1 CMAC

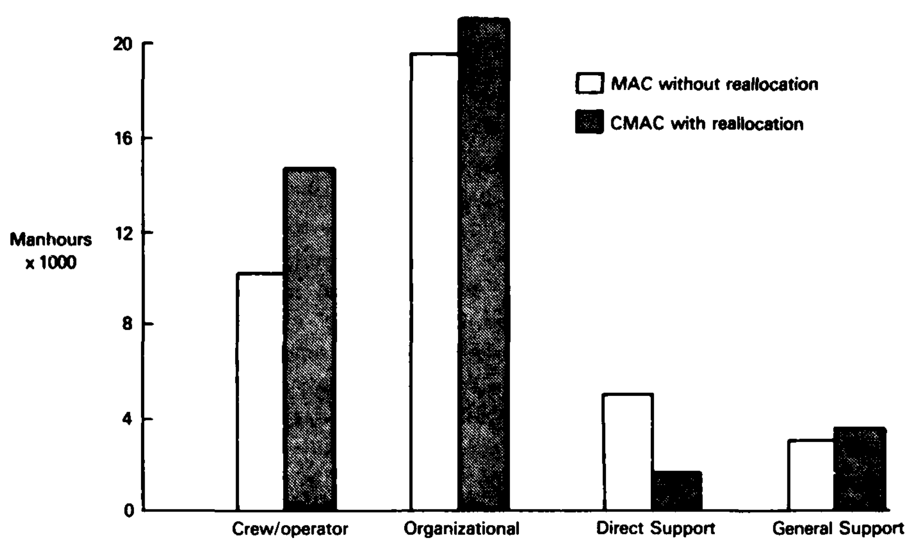
Component/ assembly	Maintenance function	Maintenance category: Crew/ operate	ORG	DS	GS	Depot
Turbocharger	Replace			4.7		
	Repair			4.1	*	
Generator	Replace		7.2			
	Repair			4.6	*	
Starting motor	Replace		3.0			
	Repair			3.1	*	
Brakes	Adjust		2.0			
	Replace			12.0	*	
	Repair			12.0	*	

Figure 5.—DS workload reallocation (MAC to CMAC)



Mission essential workload for 100 tanks in a 120 day Middle East contingency

Figure 6. Reallocation of workload—M60A1 CMAC



Even if the average workload is relatively high, there is the question of how constant the workload is over time. If the workload has large fluctuations, then manning for the average results in either large downtime for equiment waiting maintenance or the necessity for augmenting the unit during periods of peak workload. In the latter case this results in low utilization of personnel during periods when workload is below the average. In these cases it may be more effective and efficient to man the unit at less than average, as long as doing so does not result in too low a density of skills, and to provide a backup capability to augment the unit during periods of peak workload. To some extent, this concept is reflected in the multiple echelons of the current Army system.

The relative costs of decentralization versus centralization are also sensitive to the degree that peaking of workload in different units occurs at different times. For example, if the peak workload in each company of a battalion occurs simultaneously, then the number of mechanics required to support all the companies will be the same whether each company is manned to meet its peak or whether all mechanics are placed in the battalion to meet the total battalion peak workload, which in this case is the sum of the company peaks. On the other hand, if the peaks in each company occur at different times, then fewer mechanics would be required if they are assigned to the battalion and moved from company to company as required. Again, this factor is reflected in the multiple echelons and backup missions which exist in the current Army system.

It should be recognized that the level and peaking of workload, the variability in workload between units, and the degree of responsiveness required are all functions of the scenario and operational concept. From the scenario described earlier, it would appear that there would be considerable peaking of workload and considerable variability among units. On the other hand, an operational concept which moves maneuver units to influence the battle and therefore tends to equalize the combat activity across various units, also tends to equalize the logistics workload between those units.

All of these factors must be considered in determining the degree of centralization that makes sense from both an efficiency and a combat-effectiveness point of view. The composition of the workload, its predictability, the degree of responsiveness which can be provided by a centralized versus decentralized system, the cost of weapons and components, and the degree to which additional weapon systems, supply stocks, transportation, and maintenance personnel can be substituted all affect the efficiency and effectiveness of the system. These factors all differ to a significant degree for on-equipment versus off-equipment work. For on-equipment work, it appears that the more decentralized system would provide more effective maintenance at a somewhat higher cost in terms of people. Given the scenario and operational concepts described in Army doctrine, it would appear that the increase in manpower is probably not large and can be controlled by proper allocation of resources to backup elements. With the constrained numbers of weapon systems likely to be available for combat, relative to those of the adversary, it would appear that the somewhat increased manpower required for a decentralized on-equipment capability is warranted.

A somewhat different situation exists for off-equipment work, which is often more specialized and makes the low density of particular skills a more significant problem. More specialized and costly test and repair equipment is required. These and other factors all point to the need for greater consolidation in off-equipment work than in on-equipment work. To a large extent the current Army system reflects these factors. Each maneuver company has the capability to perform on-equipment work, but off-equipment work is consolidated at the division or above.

Greater consolidation of off-equipment work is generally conceded to require fewer people, less test equipment and tools, and a smaller total stock of repair parts. It is generally considered, on the other hand, to require more spares and transportation. Recent Air Force field tests and Rand Corporation analyses of aircraft systems have indicated, however, that the increase in the number of spares required is significantly less than originally thought. Test data indicate that a consolidated repair facility can repair a larger portion of the failed components. By virtue of its greater scale, it is more likely at any point in time to have the correct repair parts, or be able to cannibalize a similar component for the needed part; and to have more functioning test equipment and required personnel skills than did the previous individual decentralized facilities. These factors enable the consolidated repair point to repair and get the component back to the user in a shorter total time. In addition, test data also indicate that the consolidated system performs qualitatively better repair than the decentralized system. This results in a longer mean time between failure (MTBF) for components repaired at the consolidated facility. These two factors result in a more responsive repair and supply system, which does not require the large increases in spares stockage that were initially thought by many people to be required.

That test also showed the great value in having a locally controlled distribution system that could anticipate demands to some extent and direct repaired components to the unit with the greatest operational need. This allowed the control point to allocate spares as they became available, based on recent information, rather than having a more centralized authority outside the theater allocating spares according to more traditional decision criteria—total backorders, oldest requisition, and the like—which are not as responsive to rapidly changing requirements.

This section has discussed certain principles that appear to form the basis for a responsive, effective, and efficient tactical combat logistics system. A review of current Army maintenance structure and allocation documents indicates the feasibility of moving toward a more decentralized structure for on-equipment work and a more centralized structure for off-equipment work. Based on the scenario, operational concepts, and the other changing elements of the combat environment, it would appear such a structure would be more effective in terms of responsiveness and flexibility than the current structure. While such a structure might be somewhat more expensive, test results and analysis for other systems suggest that the increased costs may well not be prohibitive, if in fact they would be higher at all. Army studies such as the Tank Study, DRS, RGS, and Phase II appear to some degree to have reached many of these same conclusions.

ALTERNATIVE LOGISTICS SYSTEM FOR TRACKED COMBAT VEHICLES

This section describes, conceptually, an alternative combat logistics system for tracked combat vehicles. It combines many of the elements contained in the Phase II, RGS, DRS, and tank studies, but extends the concept of decentralized on-equipment work and centralized off-equipment work described in the previous sections.

The major elements include the maneuver battalions, the divisional maintenance battalion in the division, the corps maintenance battalion, maintenance elements in the COMMZ, and the CONUS depots. The maneuver battalions would be given greater capability to do on-equipment maintenance. The division's direct support structure would reflect a reorientation to an on-equipment maintenance mission of backup support to the maneuver battalions, and provision of DX points for exchangeables and supply points for repair parts. Off-equipment work (component/assembly repair) would be concentrated in the Corps or COMMZ. The Corps GS elements would possess the capability to support forward with on-equipment work during the initial combat phase, and a limited capability to repair components in support of the user. They would continue to do the more extensive on-equipment work that is beyond the capability of the division. The COMMZ GS mission would be to repair both end items and components for return to the supply system. (In this context, "supply system" includes the DX system.) The COMMZ GS mission would be expanded, particularly in wartime, to include repair and overhaul of some critical components now coded for evacuation to the CONUS.

In concept, this would result in the following: Maneuver battalions would have an organic Maintenance Company containing all organizational mechanics, recovery vehicles, etc., presently assigned to the companies of the battalions, plus additional mechanics from the existing Maintenance Battalion. These mechanics would be organizational mechanics rather than the DS/GS repairmen. The size of the Division Maintenance Battalion would be determined principally by the likely differential workload between battalions and the resulting economies to be gained by pooling on-equipment maintenance capability at the division. For example, if the combat on-equipment workload is expected to be constant in each battalion, then, in terms of efficiency and effectiveness, there would be no advantage to pooling in the division. On the other hand, if large differences in workload are expected among the battalions over time, then a large portion of the total capability would be pooled at division level and dispatched to the battalion with the greatest need in order to weight the battle logistically. It should be recognized that this is sensitive to the operational concept for combat units. To the extent that unit boundaries are changed and units moved on the battlefield to influence the battle, which therefore tends to equalize the combat load on combat units, the logistics workload between units tends to be equalized and pooling tends to produce fewer economies.

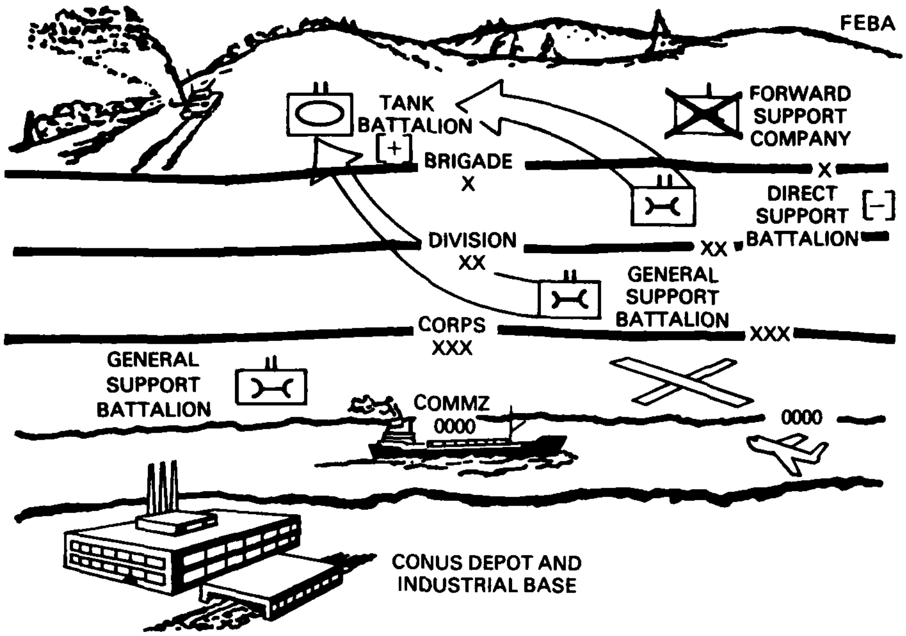
The on-equipment capability pooled at division level should be structured, manned, and equipped to be highly mobile and easily utilized as contact teams to support a fix-forward concept. The primary missions would be to support maneuver battalions with contact teams, maintain the division ASL and ORF, and operate a DX exchange point. The maintenance battalion would require vehicles suitable for transporting contact teams and repair parts on the battlefield, and communications equipment to retain control of teams and contact with maneuver battalions.

The Corps GS units would be structured, manned, and equipped to operate from semifixed facilities in the corps area. Their primary missions would be repair of components/assemblies in support of the DX program, extensive on-equipment weapon system repair that requires evacuation of the weapon from the Brigade area, maintenance of the Corps ASL and war reserve stocks located in the Corps area, and a limited capability to form and operate highly mobile contact teams to assist division and battalion maintenance elements in the division area.

The GS units in the COMMZ would be structured, manned, and equipped to operate in fixed facilities. Their primary missions would be component/assembly repair and overhaul and weapon system repair and overhaul that are beyond the capability of the Corps GS units.

Figure 7 depicts the restructured maintenance system. The forward support company is eliminated, the Tank Battalion capability is expanded, the DS Maintenance Battalion is considerably smaller and oriented to mobile contact teams, the Corps GS battalion is augmented and given some capability to deploy mobile contact teams on the battlefield but not in toto, and a GS capability is created in the COMMZ.

Figure 7. Maintenance structure alternative.



How much off-equipment capability should be located at a particular echelon should be determined by quantitative analysis on an item by item basis subject to practical constraints. For example, it would probably be unwise to have only one facility in a theater, even if it were economically optimal. A move to the COMMZ does appear to have a number of advantages, such as use of fixed facilities; advantages of scale in terms of test equipment, repair parts and skilled personnel; and the ability to capitalize on production techniques not amenable to the combat environment in the forward area.

The discussion in this and previous sections has described a concept for maintenance of tracked vehicles different from the current Army concept, and has pointed out the major elements and considerations for detailed analysis. Contingency maintenance plans for the M60A1 tank indicate the desirability of realigning more of the on-equipment workload from DS to the Organizational level and more of the off-equipment (component repair) workload from DS to GS. Implementing only the CMAC reallocations would result in 53 percent of the DS workload being allocated to the organizational level and 15 percent to the GS level. The reallocation potential for new equipments would probably be higher because of their increased modularity and maintainability and the increased sophistication of their subsystems.

MACRIT data indicate that tracked combat vehicles, although making up only about 40 percent of the vehicles in an armored or mechanized infantry division, account for at least 75 percent of DS workload. Assuming that the CMAC reallocation potential is roughly indicative of the potential for other tracked vehicles, about 300 spaces could be realigned from the division maintenance battalion to the maneuver and other operating battalions. That would enhance their responsiveness to on-equipment maintenance demands and reduce the time awaiting transportation or transporting weapons back to where repair resources are available. (Analysis indicates this would account for approximately half the time weapons would be unavailable for combat.) An additional 100 spaces would be realigned to corps or theater general support facilities. Based on Army MACRIT planning factors, transferring spaces to a fixed repair facility in the COMMZ, for example, would increase productivity 25 percent because of increased man-hour availability alone. Such a realignment would increase the Army's component repair capability by an amount equivalent to adding 300 to 400 spaces to the Army's force structure.

Based on results with other systems, the benefits from greater centralization of component repair would likely be much greater than those attributable to increased man-hour availability. Repair in production-oriented facilities is likely to have better quality than repair performed under battlefield conditions. The degree of movement to the rear is very sensitive to supply stockage and transportation assumptions. Analysis of other weapon systems has found that past intuition (and even some empirical analysis) has been misleading, particularly in regard to the level of stockage required to support more centralized component repairs. The maintenance/supply/transportation system is extremely complex and the interactions are not always intuitively obvious.

Two additional elements are critical to the successful operation of a responsive theater logistics capability: logistics management and transportation. These two factors are even more germane to the scenario, the environment, and the alternative maintenance and repair parts supply system discussed above.

In a dynamic battle, priorities often change, combat intensity for units rises and falls, and combat damage varies across units. Such a situation demands a management and control system that can both anticipate and immediately react to changing demands. Currently, requirements calculations and supply distribution are based on fixed, forecasted activity rates and historical demand levels. Furthermore, the materiel management system depends upon surrogate measures to determine need. Thus, fill rate and back order rate, for example, take on value unto themselves. There is an inherent assumption that all demands for a given item for a given system are of equal importance, remain relatively constant over time, and either change slowly or in response to planned events known well in advance. In a European war, such preplanned priority systems would fail. There must be a system to deal with the differential importance of individual weapons, classes of weapons, units, and missions as they vary over time. Functional proxy measures will not do the job. More direct operational indicators are needed, based on full understanding of the local situation. This understanding is much more likely to reside in the theater than in CONUS item managers.

In a dynamic environment, it is likely that serious resource imbalances will develop within units and degrade their capability. Thus, more routine reallocations of *theater resources to higher-priority units is likely to increase theatre capability.* This also implies that tasking and planning must be based on frequently updated status information.

The Army's current theater materiel management system has limited responsibility and capability to satisfy these requirements. In addition to the normal logistics staffs, the system consists of the FASCO (Forward Area Support Coordination Officer), the division MMC (Materiel Management Center), the corps MMC, and the theater MMC. The FASCOs are organic to the Division Support Command (DISCOM) and are located in the brigade area. They coordinate combat service support missions between the brigade and DISCOM elements operating in the brigade support area, provide liaison between DISCOM elements and the brigade, and provide information on the logistical situation within the brigade area to the DISCOM headquarters. The MMCs provide centralized and integrated materiel (supply and maintenance) management for all classes of military supply except medical, communications security, rail mission equipment, and classified maps. (A more detailed discussion of the missions and functions of these elements is provided in the Appendix.) These MMC elements certainly provide the nucleus and basis for a theater logistics management system of the kind we believe is required. The primary changes required for these elements appear to be the augmentation or development of the required information systems and procedures needed for the wartime mission. There do appear to be major deficiencies, however, in the quantity of supplies available in theater and the physical means for handling and moving them when they arrive in theater. The Army recognizes these deficiences and has begun programming and budget actions to solve them.

Currently, there are insufficient repair part companies to handle the required repair parts flow. The Direct Supply System (DSS), in peactime, routes repair parts from the depot direct to the requisitioning unit. In wartime, a much larger portion of the repair parts flow must be handled at the corps. This requires repair parts companies in the corps. War reserve stock positioned in theater, stockage flowing through the corps, repair parts companies to handle the supplies, and augmented MMCs with the required information and procedures will provide the capability to weight the battle logistically and respond to dynamic changes in requirements only if transportation is available to move the supplies to the point of need. Currently, the intratheater transportation system is inadequate to meet planned requirements.

Repair parts account for only a small fraction of the total transportation requirement, but their weight and cube are far less important than their criticality to weapon *availability and combat capability. Consequently, dedicated transportation assets may* be warranted—all the more so for the alternative maintenance concept, which renders the combat unit almost totally dependent on a consolidated intermediate repair capability for components and assemblies. Further study and test of these concepts must ensure that transportation can be made available to move components and assemblies promptly to the point of need, and evacuate unserviceables to the repair facilities.

Careful consideration should be given to the potential cost-effectiveness of a dedicated repair parts transportation system.

All of these factors, maintenance manpower, supply pipeline, and transportation, are subject to detailed empirical analysis. Even when using data from the current system, however, empirical analysis often has limited value. Field tests provide a further level of analysis, and are almost always required before even limited confidence can be gained in fairly radical changes in concepts and procedures. Field tests are not easy to conduct, however, as illustrated by the Army's experience with the DRS and RGS tests. It is difficult to structure such tests, more difficult to obtain required funds and the units to conduct the tests, and, finally, difficult to analyze test results in a way that provides meaningful information about the concept's value in a combat situation. Such tests are vital, however, if innovation is to be tried and sufficient confidence gained to implement changes to a system that is so vital to combat capability.

V. FURTHER ISSUES AND OBSERVATIONS

This section discusses a number of issues and observations, some of which are only indirectly related to logistics structure, that warrant separate attention and discussion.

ADEQUACY OF SUPPORT RESOURCES

A hypothesis expressed by the DRMS at the outset was that resource decisions over the past several years may have overemphasized peacetime efficiency to the detriment of wartime effectiveness. The Army's Tank Weapon System Management Study identified funding constraints as a major influence on logistics. It said, "The need for peacetime efficiency drives logistical organization, policy and procedures. It also presents the commander and logistician with the serious and continuous challenge of balancing this effectiveness."[16] The recently completed Army study of Combat Service Support (CSS) indicated a force structure and deployment plan imbalance in terms of the amount of CSS available to support the existing combat force structure. This shortfall, to some extent, is due to past action to increase the "tooth-to-tail" ratio, increase "combat" forces in Europe while simultaneously reducing support forces, and "heavy-up" and modernize Army divisions with sophisticated armor and mechanized equipment without concomitant increases in logistics capability. In Europe this has resulted in a logistics base which is, at most, marginally adequate to satisfy peacetime demands. As the Phase II study pointed out, the current structure, procedures, and resources would not be adequate to handle a Warsaw Pact/NATO conflict even with the planned augmentation of resources from CONUS. While the present case study has dealt almost exclusively with alternatives for increasing the effectiveness of logistics support within current budget constraints, the DRMS review has only reinforced our initial hypothesis, and the view held by others, that the incessant quest over the past decade or more for peacetime efficiencies in the logistics establishment has severely degraded peacetime combat readiness and the capability to utilize "combat" forces effectively in a large-scale conflict. As pointed out in Chaps. I and II of the main report, questions of both adequacy and efficiency of support must receive more attention in the future if maximum combat capability is to be realized within the constrained resource levels likely to exist. The question of adequacy is also important because of its side-effects on efficiency.

Inadequate support resources, decisions to reduce support that are perceived as unwarranted or shortsighted, and the perception of an adversarial relationship in the budgetary process often suppress innovation and the search for real efficiencies, which in the long run would have much more lasting effect on both combat capability and cost-effectiveness. These effects appear to be particularly perverse where an innovation requires an increase in one type of resource that would permit reductions in other types of resources, or where the effects of the change are somewhat uncertain. In the first case, managers at all levels are extremely reticent to identify resource trades that

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[16] *Tank Weapon System Management*, ca. 1977, p. III-5.

would increase efficiency or effectiveness if they perceive there is a fair chance they will lose the resource identified for trade but not get the resource needed to effect the improvement or implement the change. In the second case, managers will not put resources at risk by identifying an innovation which has less than certain payoff if they think the resources will not or may not be restored if the innovation does not prove out as expected. While DRMS has not systematically explored these effects, discussions with managers regarding how innovations can be encouraged have certainly reinforced the fact that the effects are real and could be of significant magnitude. These effects would restrain innovations with efficiency potential more during periods of constrained or shrinking resource levels than during periods of unconstrained or expanding resource levels, thus making them even more perverse.

ADEQUACY OF RESERVE COMPONENT SUPPORT RESOURCES

The preceding issue of adequacy of support resources mentioned the force structure and deployment plan imbalances between combat and service support forces. This imbalance is exacerbated by the fact that fully 80 percent of the GS Heavy Equipment Maintenance Companies (HEMCO) are in the reserve components. This fact alone does not constitute the problem because, everything else being equal, the deployability and viability of either a reserve or an active duty HEMCO in CONUS should also be equal. In fact, a strong case can be made in favor of the reserve unit. At issue is the fact that the two situations are not equal. Indications are that the reserve component HEMCOs, for example, are neither equipped nor trained to support a wartime Army. They do not know which units and what type of equipment they would support in war. They do not normally work on equipment assigned to active Army units (such as the M60A3 tank), nor do they have the necessary tools, equipment, or training to perform their required maintenance functions. The frequent redesignation of reserve unit missions has even further compounded the problem. The Army is aware of this problem and is attempting to resolve it by means of affiliation-type training for reserve units in Europe through the COSCOM Roundout program. The Army should be encouraged to continue and accelerate their efforts in this direction.

SUPPLY REQUIREMENTS

Within the previously discussed Army six principles, emphasis is given to providing a considerable quantity of combat-essential spares to the theater forces. Present stockage is based on peacetime demand data that may differ from wartime requirements both in quantity and type of items stocked. A case frequently cited is the wiring harness for a tank, which has few peacetime demands but is expected to have high combat-damage-generated demands. It is essential that the Army continue its efforts to predict (and provision for) combat consumption of repair parts by means of its Wartime Repair Part Consumption (WARPAC) and other planning guides. Further, once requirements are identified and quantified, funding must be provided to stock the items.

MAINTENANCE ALLOCATION CRITERIA (MACRIT)

In reviewing Army maintenance Tables of Organization and Equipment (TOEs) and how they are devised, deficiencies in the Army MACRIT system for determining maintenance manpower requirements were apparent. The Army is aware of these deficiencies and has proposed a program for revamping the MACRIT system. The proposed changes would, we feel, go a long way toward correcting the existing deficiencies. A system that relates maintenance manpower requirements more directly to operational mission capabilities, e.g., weapon system availability or turnaround time, would make it possible to distribute manpower and maintenance capability with greater certainty of enhancing mission effectiveness. This would permit consideration of workoad variability and manpower utilization and their effects on both combat effectiveness and logistics efficiency, and enable a better balance between the two. Under the current system, there is no way to adequately assess the effect of changes in logistics manpower or structure on combat capability. The Army should be encouraged to continue its efforts to relate maintenance manpower requirements to combat effectiveness.

CREW/OPERATOR MAINTENANCE WORKLOAD

Maintenance that the crew/operator is required to perform is not directly considered in determining crew/operator requirements. For modern weapon systems, this could lead to an inordinate amount of work being placed on the crew, to the detriment of their combat training and maintenance performance and to the combat readiness of the weapon. While DRMS agrees with the Army that placing some responsibility on the crew for maintaining their equipment is desirable and may help reduce equipment abuse and a "we break it, you fix it" attitude, it is critical not to place an unrealistic burden on the crew.

In reviewing the CMAC for the M60A1 tank, for example, we noted that almost 25 percent of all maintenance man-hours were the responsibility of the crew. If the reallocations suggested in the CMAC were made, the maintenance workload on the crew would increase by 50 percent during the contingency/combat period. These factors would appear to warrant a careful reassessment of how much maintenance workload can realistically be assigned to the crew without detrimental effects. Alternatives would be to assign more of the maintenance functions to the organizational mechanics, or increase the number of crew members assigned to the companies or battalion to compensate for maintenance workload. Either of these alternatives would require additional manpower authorizations. Further analysis is required to determine if such increases would be warranted by a corresponding increase in combat readiness/capability.

PRODUCTION-LINE ORIENTATION IN COMBAT THEATER

One of the major themes of this study has been that the theater should be enabled to increase the responsiveness and flexibility of weapon system maintenance and repair parts supply. One alternative discussed for doing this is to increase the consolidation of component repair in the theater to capture economies of scale and increase productivity. Care must be taken in planning and implementing any such structure to ensure that the capability is in fact responsive and flexible. There is always a tendency to make such operations as "efficient" as possible. It should be recognized that some production techniques, such as production-line activities, while theoretically more efficient, may be inherently less responsive and flexible in modern warfare and particularly in a resource-constrained environment where short-term shortages of combat-essential items are critical. The question of what types of maintenance production techniques are most appropriate for the combat theater needs further examination.

VI. CONCLUSIONS

The DRMS examination of logistics support for Army Tracked Combat Vehicles has identified a number of issues which warrant further attention and evaluation. The Army has identified many of these issues and is taking steps to resolve them that, in general, are consistent with the direction that our examination indicates is the correct one. Our alternatives appear to differ only in degree with changes currently under study and evaluation within the Army.

It is generally recognized that some steps taken in the past in the interest of peacetime efficiency have eroded potential wartime effectiveness out of proportion to any peacetime savings. (And in some cases, the savings originally estimated have not been realized.) The Army has programmed changes in logistics support that will greatly alleviate currently identified shortfalls. Changes in maintenance MOSs, initiatives to improve the readiness of Reserve/Guard logistics units, and changes in funding and deployment priorities, are all expected to improve the capability of the Army logistics structure to respond effectively to combat demands.

In some cases, the DRMS recommends that the Army move more aggressively. There is a need to evaluate somewhat more drastic changes in current concepts, structures, and procedures in order to perceive the most effective changes and their relative costs. A sharper differentiation between on-equipment versus off-equipment repair would stimulate structures that might be significantly better than current ones. A logistics concept emphasizing rapid turnaround of weapon systems at the front, coupled *with greater centralization of off-equipment repair* to the rear of the immediate combat area, should increase effectiveness significantly. These findings tend to reinforce the results of the Army's Tank Study, Phase II, DRS and RGS.

In any major conflict in the foreseeable future, logistics resources will be severely constrained and the ability to reallocate resources quickly will be critical. The current system does not appear to be structured or equipped to provide adequate theater command and control of logistics resources in a combat environment. Simple and direct means are needed for expediting movement and repair of critical components and for cross-leveling among units based on expected needs. Such procedures must be worked out and exercised in peacetime.

Army supply stockage and distribution policies should be based on expected combat requirements, not peacetime demands.

The Army should continue its efforts to completely revamp the MACRIT system for developing manpower requirements. A system that relates maintenance manpower requirements to operational mission capabilities will make it possible to distribute manpower and maintenance capability with greater certainty of enhancing mission effectiveness.

There appears to be a need for endowing the Army with a greater capability for developing and evaluating support alternatives. We recognize that the Army has examined many options over the years, but most have involved fairly marginal changes. This is understandable in view of the criticality of such changes for combat capability and the difficulty in obtaining the support necessary to test such alternatives adequately. Much of the support for such evaluations and field tests must come from outside the Army if adequate resources are to be made available.

Phase II, RGS, DRS, CABL, restructuring of maintenance MOSs, extensive modernization programs, and movement toward more sophisticated equipment all provide both the opportunity and the necessity for evaluating alternative support structures, some of which may differ radically from current ones. The decisions of the next few years are likely to determine the Army logistics capability for the next decade and more and, in turn, the Army's combat capability. Because the problems are complex and solutions are not easy, caution in implementation is certainly warranted.

Appendix
TRACKED VEHICLE MAINTENANCE AND SUPPLY SYSTEM

INTRODUCTION

This appendix describes in somewhat more detail the current Army system for providing maintenance and supply support to tracked combat vehicles. As noted in Section III, the basic Army philosophy is that maintenance is a command responsibility and should be performed at the lowest level practicable. Maintenance responsibility and capability begins at the crew/operator level in the company and continues back through successive levels at battalion, division, corps, communications zone and, finally, to the wholesale depot level. There is a similar structure for repair parts supply support. Figure A-1, extracted from an Army briefing, depicts the Army Maintenance System supporting a tank battalion on the battlefield.

MAINTENANCE

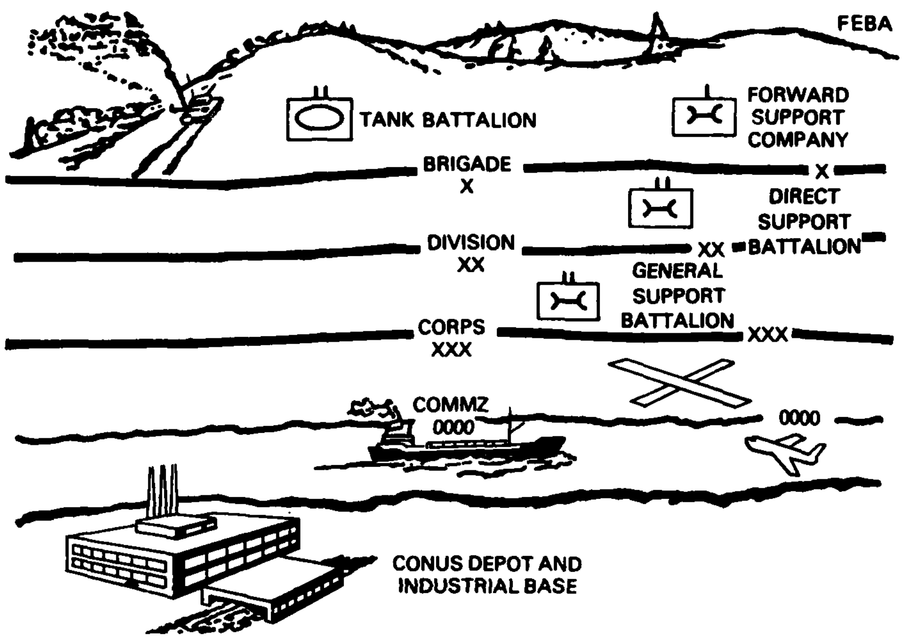
The following discussion will describe the various categories and levels of maintenance shown in Fig. A-1. For illustrative purposes we will use an Armored Division. Figure A-2 shows the organization of the Armored Divisions as depicted in U.S. Army Armored Reference Data, ST 17-1-1, p. 1. Tables A-1 and A-2, based on information from the same source, summarize the number of personnel and vehicles, respectively, for major elements in an armored division. Note that an armored division has some 16,700 people and 5,500 vehicles, of which 1,500 are tracked combat vehicles. The Engineer Battalion has an additional 162 pieces of engineer-unique equipment, not included. Table A-2 shows the total number of tracked combat vehicles, the number in selected major categories, and the number of each assigned to the major elements.

As shown in Table A-1, there are 2,500 maintenance personnel, or personnel assigned to maintenance organizations, in an armored division excluding those unique to the aviation, signal, and engineer battalions. Many of the 2,500 support directly or indirectly equipment other than tracked combat vehicles, while 800 tracked vehicle mechanics/repairmen and 150 tank turret mechanics/repairmen are almost exclusively dedicated to tracked vehicles and tanks, respectively. The tracked vehicle mechanics/repairmen are distributed over some 80 company/battery/troop-sized units including the individual tank companies.

Organizational Maintenance

The Tank Battalion has two kinds of organic maintenance capability: crew/operator and organizational mechanics. The crew/operator is responsible for routine checks, cleaning, lubrication, and adjustments. The organizational mechanics perform

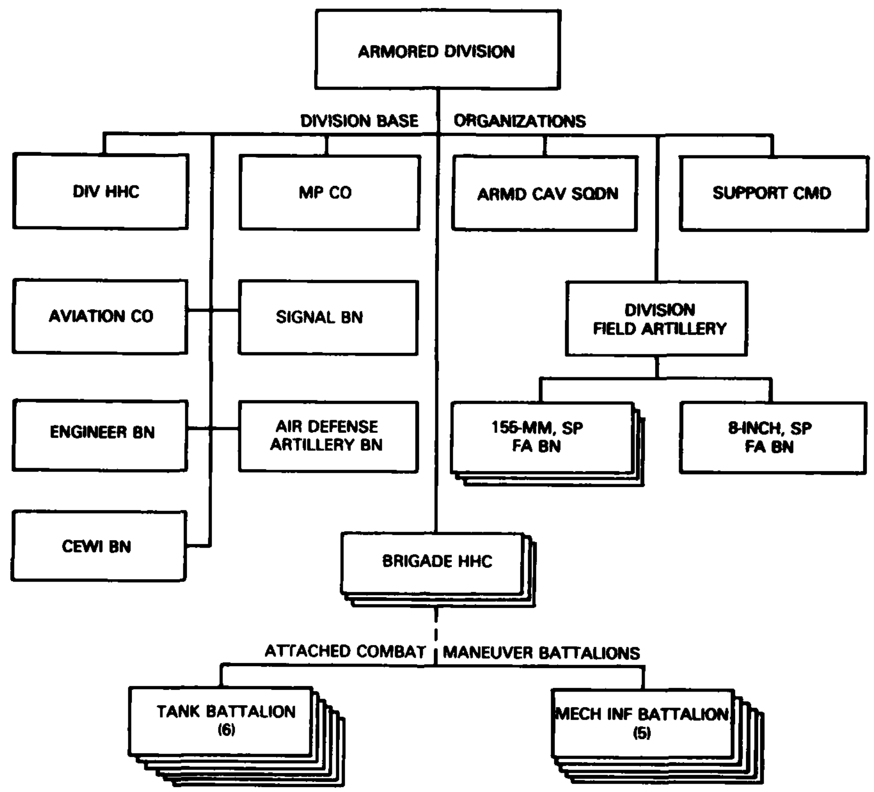
Figure A-1. The Army maintenance system



inspections, replace components/assemblies, replace piece parts, and evacuate unserviceables to the battalion's Direct Support Maintenance element. Organizational mechanics are located in each of the companies to support the company's equipment, and in the Tank Battalion Maintenance Platoon that supports all battalion equipment. Table A-3 shows the maintenance elements of a Tank Battalion and the number of tank vehicle mechanics and tank turret repairmen in each. The Battalion Maintenance Platoon also maintains each company's Prescribed Load List (PLL) of repair parts. This consists of about 170 lines, of which about 70 are tank-related and 40 are common hardware items. Examples of items in the PLL are track pads, spark plugs, starters, and generators.

Some battalions have consolidated operational control and scheduling of all mechanics at battalion level even though the mechanics remain on the Modified Table of Organization and Equipment (MTOE) of the subordinate companies. The Division Restructuring Study (DRS) is testing consolidation of all mechanics at battalion level, including changing the TOEs. This effectively pools the capability of the 35 tracked

Figure A-2. Armored division organization chart.



vehicle mechanics, for example, at one point of control rather than at six points for the standard TOE.

Direct Support Maintenance

The next category of maintenance above Organization is Direct Support (DS) Maintenance. There is one Direct Support Maintenance Battalion in each division. Figure A-3 shows the major elements of the Maintenance Battalion.

The Maintenance Battalion performs DS level maintenance, such as malfunction diagnosis, limited repair, calibration and alignment of components, tank repair (repair or replace components/assemblies), armament repair, body work/welding, and

Table A-1.—Armored division: personnel

Unit	Total	Maintenance[1]	Track vehicle Mech/RPMN[2]	Tank turret Mech/RPMN
Div HHC	191	11		
Aviation Co	96	7		
MP Co	191	10		
Signal BN	609	55		
Engineer BN	961	95	15	1
Brigade HHC (3ea)	112	12	5	
ARMD CAV SQ	815	81	38	7
Support CMD	2,536	1,164	247	69
Air Def Arty BN	583	51	20	
Div Arty	2,539	108	38	
Tank BN (6ea)	552	87	35	12
Mech Inf BN (5ea)	901	72	37	
Div total	16,734	2,476	758	149

[1] Does not include aircraft, engineer, signal equip.
[2] Does not include engineer equip.

Table A-1

direct exchange of parts with Tank Battalions. It also maintains the division's Authorized Stockage List (ASL). The ASL typically consists of 4,000 to 5,000 lines, of which 900 are tank-related and 1,200 are common hardware items. Items include engines, transmissions, differentials, final drives, gun tubes, etc. Wherever possible, the DS Battalion performs maintenance at the point of failure using a contact team,

Table A-2.–Armored division: tracked combat vehicles

Unit	Trucks[1]	Total[2] tracks	Tanks	Cargo carrier & APCs	Mortar & TOW carrier	Self-propelled artillery	Air defense artillery	Recovery vehicle
Div HHC	32	2		2				
Aviation Co	22							
MP Co	7							
Signal BN	142							
Engineer BN	122	57		43				3
Brigade HHC (3ea)	24	5		4				1
ARMD CAV SQ	81	116	27	52	9			5
Support CMD	478							4
Air Def Arty BN	100			12			48	4
Div Arty	437	176		105		66		9
Tank BN (6ea)	78	91	54	28				7
Mech Inf BN (5ea)	72	103		69	22			6
Div total:	2,441	1,507	351	731	119	66	48	100

[1] Does not include aircraft, engineer, signal equip.
[2] Does not include engineer equip.

rather than evacuating the equipment to the division rear. Note that a Forward Support Company of the Maintenance Battalion operates in each brigade area, supporting the maneuver battalions and any other units in the brigade area on an area basis. The Missile Support Company provides DS level maintenance for all missiles in the division on an area basis. The Light Maintenance Company provides direct support electronics equipment maintenance, except for missile systems, for division elements located to the rear of the brigade area, and backup support to the Forward Support Companies. The Heavy Maintenance Company provides direct support maintenance for mechanical, armament, and construction equipment to units of the division not supported by Forward Support Companies, and provides direct support maintenance for all refrigeration and chemical equipment, and supplementary and backup support to the Forward Support Companies.

There is normally a DS Maintenance Battalion within the Corps Support Command to perform DS maintenance for units in the corps area to the rear of the divisions.

Table A-3.—Tank battalion maintenance elements

	Total personnel	Track VEH mechanics	Tank turret mechanics
HQ & Hq Co			
Co Maint Sec	11	8	
BN Maint Plt	30	9	3
Tank Co (3 ea)			
Main Sec	12	4	3
Combat Support Co			
Main Sec	10	6	
BN Total	87	35	12

General Support Maintenance

The next level of maintenance above Direct Support is General Support Maintenance. The division relies on the General Support Maintenance Battalion located in the corps for general support. The corps General Support Battalion performs repair and limited overhaul of end items and compónents/assemblies, heavy body, hull, turret, and frame repair; backup direct support to the division; and direct exchange of assemblies with DS units. Maintenance support for tracked vehicles is primarily provided by Light Equipment Maintenance Companies for communications/electric equipment and Heavy Equipment Maintenance Companies for mechanical, armament, and construction equipment.

Traditionally, GS units have repaired in support of the supply system while DS units have repaired for return to the user. As discussed in the text, the new concept recently approved by the Army would concentrate corps GS units on repair for return to the user, while a GS capability in the COMMZ would be responsible for repair in support of the supply system.

Figure A-3. Armored division maintenance battalion.

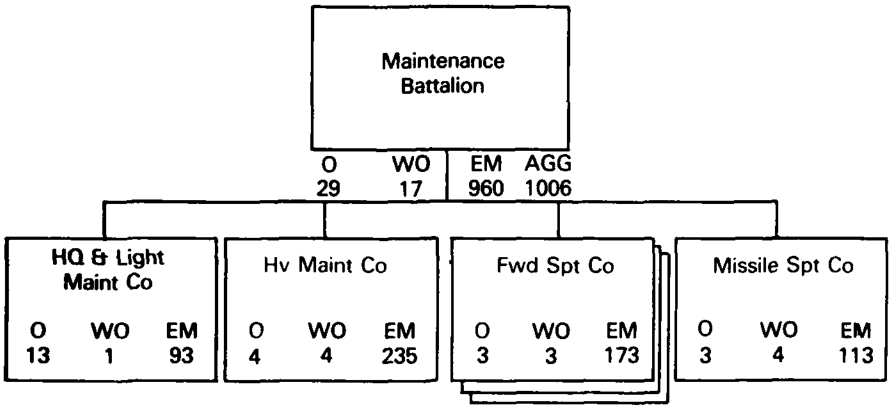


Figure A-3

Additional GS units may be located to the rear of the corps. Currently, the 21st Support Command in Europe has a limited GS capability to act as a backup to corps units and to support theater Army assets. In addition, there are two depot-level support facilities in Europe operated by DARCOM. One facility, at Mainz, does depot-level repair and overhaul of tracked combat vehicles, components, and assemblies, while a facility at Oberamstadt is a tire rebuild facility.

Figure A-4 summarizes the maintenance echelons, categories, and functions as described above.

REPAIR PARTS SUPPLY SYSTEM

Figure A-5 summarizes the flow of requisitions for repair parts and their distribution. Organizational level maintenance units obtain repair parts to fill their PLL from the supporting DS unit. The DS unit requisitions replenishment parts through the division, corps, and theater Material Management Centers (MMC). The National Inventory Control Point in CONUS cuts a Material Release Order (MRO) in response to the requisition, which causes the wholesale system to ship the item. Under the Direct Supply System (DSS), repair parts for a particular unit are consolidated at one of three CONUS area-oriented depots (AOD). For Europe, the consolidation point is New Cumberland Army Depot at New Cumberland, Pennysivania. The shipment then goes by air to Europe and by truck directly to the unit requisitioning the items.

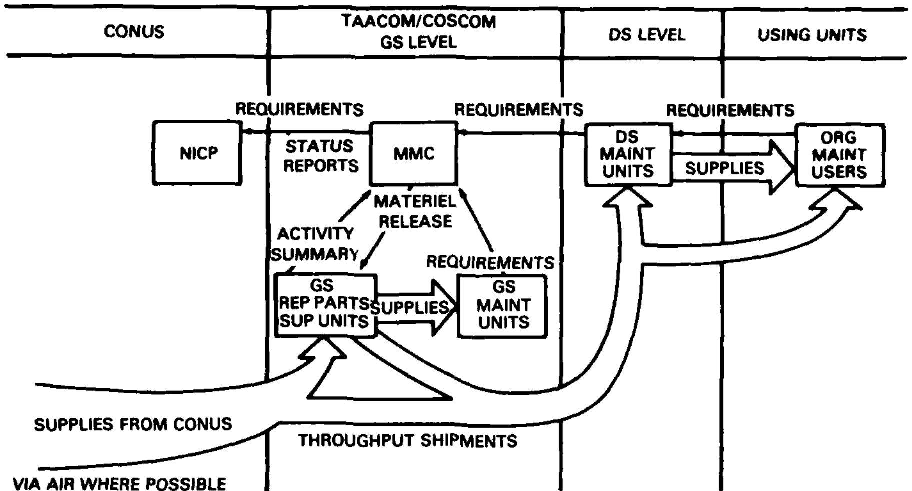
Figure A-4.—Summary of maintenance organization and functions.

LEVELS OF OPERATION	SUBORDINATE MAINTENANCE ECHELONS	MAINTENANCE		WHOM SUPPORTED
		CATEGORY	FUNCTIONS	
COMPANY	MAINTENANCE SECTION	ORGANIZATIONAL	RECOVERY EVACUATION OF UNSERVICEABLES PREVENTIVE MAINTENANCE SVCS MINOR ADJUSTMENT COMPONENT & ASSEMBLY REMOVE & REPLACE	SELF
BATTALION*	MAINTENANCE PLATOON	ORGANIZATIONAL	EVACUATION OF UNSERVICEABLES TECH SUPV OF COMPANY MAINTENANCE PLL STOCKAGE FOR COMPANIES	SELF COMPANY OVERFLOW
BRIGADE**	MAINTENANCE COMPANY (FORWARD SUPPORT)	DIRECT SUPPORT	TECHNICAL ASSISTANCE COMPONENT LIMITED REPAIR END ITEM LIMITED REPAIR COLLECTING POINT EVACUATION OF UNSERVICEABLES ALL ORGANIZATIONAL FUNCTIONS	SELF COMBAT BATTALIONS
DIVISION	MAINTENANCE BATTALION (DS)	DIRECT SUPPORT	TECHNICAL ASSISTANCE COMPONENT REPAIR END ITEM REPAIR REPAIR PARTS SUPPLY DIRECT EXCHANGE (DX) OPERATIONS OPERATIONAL READINESS FLOAT (ORF) EVACUATION OF UNSERVICEABLES	SELF BRIGADES (F.S. COMPANIES) COMBAT BATTALIONS
CORPS	MAINTENANCE BN (DS)	DIRECT SUPPORT	SIMILAR TO NEXT ABOVE	DS FOR UNITS IN CORPS REAR AREA
CORPS	MAINTENANCE BATTALION (GS)	GENERAL SUPPORT	TECHNICAL ASSISTANCE REPAIR INTERNAL PIECE PART HEAVY END ITEM REPAIR UNSERVICEABLE END ITEM COLL/CLASS/EVAC CANNIBALIZATION POINT REPAIR PARTS SUPPLY ALL DS & ORGANIZATIONAL FUNCTIONS	GS FOR DS UNITS IN CORPS AREA SUPPLY SYSTEM
COMPANY	DEPOTS	DEPOTS	TECHNICAL ASSISTANCE OVERHAUL END ITEMS & ASSEMBLIES EQUIPMENT MODIFICATIONS MANUFACTURE	SUPPLY SYSTEM GS UNITS

* Some Combat Battalion commanders have exercised the option of consolidating their subordinate company maintenance sections within the battalion maintenance platoon. Regardless of organizational variations, all the company Prescribed Load List (PLL) repair parts are separately maintained centrally by the battalion maintenance platoon.

** Even though the brigade table or organization and equipment (TOE) does not reflect an organic maintenance unit, the forward support company is habitually placed in support of one specific brigade and moves as part of that brigade's trains.

Figure A-5. Flow of repair parts and requisitions.



Source: Department of the Army Field Manual 100-10, *Combat Service Support*, p. 9-29.

Direct Exchange (DX) System

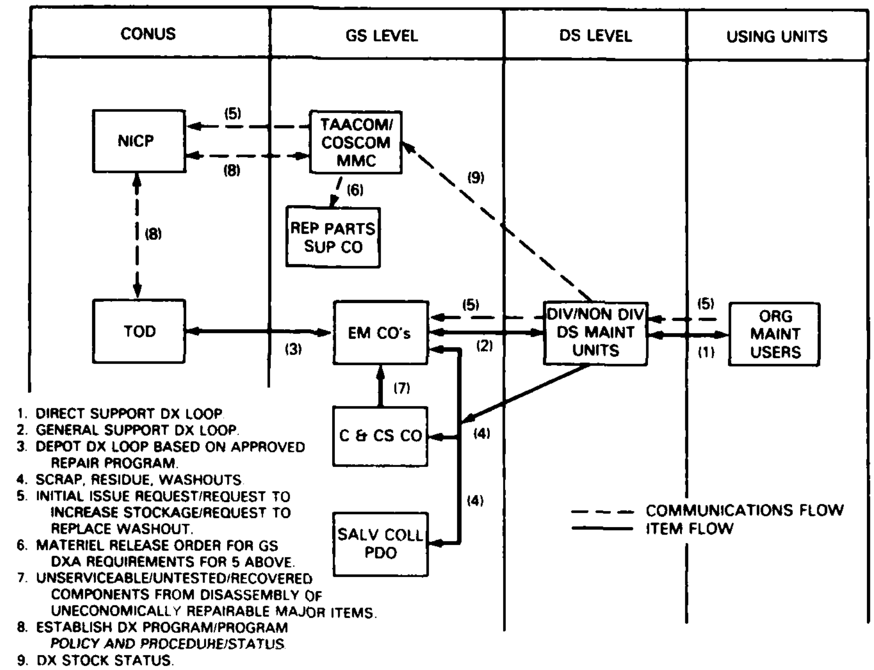
Figure A-6 summarizes the flow of Direct Exchange components and assemblies. For DX items, the user exchanges a malfunctioning reparable for a repaired item on a one-for-one basis. The DX exchange point then repairs the item and puts it back in its DX stock. DX loops operate between organizational and DS level and between DS and GS level, depending upon who is responsible for the repair.

MATERIEL MANAGEMENT AND DISTRIBUTION

In addition to the normal logistics staff, there are two elements of the Division Support Command (DISCOM) with coordination and resource management responsibilities: the FASCO (Forward Area Support Coordination Officer) and the DMMC (Division Materiel Management Center).

The FASCO, located in the brigade area, coordinates combat service support missions between the brigade and DISCOM elements operating in the brigade support area, provides liaison between DISCOM elements and the brigade, and provides information on the logistical situation within the brigade area to the DISCOM. FASCOs are organic to the Headquarters Company of the DISCOM in airborne and airmobile divisions and implemented by MTOE in armor, infantry, and mechanized infantry divisions.

Figure A-6. Direct exchange schematic.



Source: Department of the Army Field Manual 100 10 P9 30

The Division Materiel Management Center (DMMC) is a separate TOE unit assigned to the DISCOM headquarters. The DMMC consists of approximately 150 people primarily devoted to the management of division supplies. It provides centralized and integrated (supply and maintenance) management for all classes of military supply except medical, communications security equipment, rail mission equipment, and classified maps. The DMMC: (a) determines requirements for development and technical supervision of division ASLs, PLLs, and ORF lists; (b) procures all supplies received by the division for which the center is reponsible and directs their distribution; (c) manages the division master property records and equipment status reporting system; (d) manages the Class IX (repair parts) supply system including development, approval, and maintenance of ASLs and PLLs; (e) operates an integrated maintenance management information program; (f) manages the Class II supply system; and (g) determines ASL mobility requirements in time of war.

Two sections, the Class IX Supply Section and the Maintenance Section, manage the division's repair parts and maintenance resources. The Class IX Supply Section receives, edits, and forwards all repair parts supply requests from the maintenance battalion DSUs. It also develops and maintains the ASLs and monitors and publishes all PLLs.

The Maintenance Section is the centralized and integrated division maintenance management activity for all division equipment except Class VIII, communications security equipment, rail mission equipment, and classified maps. It manages both organizational and direct support maintenance. It operates the maintenance reporting and management system to maintain status information on combat-essential equipment and provide material readiness information. It develops maintenance plans for division combat operations, generates disposition instructions for unserviceables which exceed the repair capability or capacity of the division maintenance units, and develops requirements for transportation to evacuate the unserviceables from the division area.

ORGANIZATIONS AND FACILITIES VISITED

In the course of making these case studies the contributors visited several installations and discussed current and possible logistics support concepts with a large number of people.

The following are the units and locations that the contributors visited.

Army Logistics

Hq Department of the Army
Pentagon, Washington, DC

Hq U.S. Army, Europe (USAREUR)
Heidelberg, Germany

Hq U.S. Army Materiel Development
and Readiness Command (DARCOM) Alexandria, Virginia

Hq V Corps
Frankfort, Germany

21st Support Command
Kaiserslautern, Germany

Army Logistics Center
Fort Lee, Virginia

Depot Systems Command (DESCOM)
Letterkenny, Pennsylvania

3rd Armored Division
Frankfort, Germany

New Cumberland Army Depot
New Cumberland, Pennsylvania

Letterkenny Army Depot
Letterkenny, Pennsylvania

Tobyhanna Army Depot
Tobyhanna, Pennsylvania

Miesau Army Depot
Miesau, Germany

Combat Equipment Group Europe (CEGE)
Funari Barracks, Germany

U.S. Army Tank Automotive Readiness Command (TARCOM)
Detroit, Michigan

II Corps Support Command (COSCOM)
Fort Hood, Texas

1st Cavalry Division
Fort Hood, Texas

Anniston Army Depot
Anniston, Alabama

Mainz Army Depot
Mainz, Germany

Kaiserslautern Army Depot (KAD)
Kaiserslautern, Germany

8th Maintenance Battalion (GS)
Frankfort, Germany

51st Maintenance Battalion (DS)
Spinelli Barracks, Germany

66th Maintenance Battalion (GS)
Kaiserslautern, Germany

122nd Maintenance Battalion (DS)
Frankfort, Germany

1/40th Field Artillery Battalion
Frankfort, Germany

150th Heavy Equipment Maintenance Company, GS
Carson City, Nevada

Troop Support and Aviation Materiel Readiness
Command (TSARCOM)

101st Air Assault Division
Fort Campbell, Kentucky

New Cumberland Army Depot
New Cumberland, Pennsylvania

Corpus Christi Army Depot
Corpus Christi, Texas

70th Transportation Battalion (AVIM)
Coleman Barracks, Germany

205th Aviation Battalion (AVIM)
Frankfort, Germany

503rd Aviation Battalion (AVIM)
Frankfort, Germay

Navy Logistics

Hq Department of the Navy
Pentagon, Washington, DC

Navy Ships Parts Control Center
Mechanicsburg, Pennsylvania

Naval Ship Engineering Center
Mechanicsburg, Pennsylvania

Navy Air Logistics Center (NALC)
Patuxent Naval Air Station, Maryland

Naval Air Repair Facility (NARF)
Jacksonville, Florida

Aviation Supply Office (ASO)
Philadelphia, Pennsyvlania

Naval Air Station (NAS)
Miramar, California

USS SARATOGA
Jacksonville, Florida

COMNAVAIRLANT
Norfolk, Virginia

Air Force Logistics

Hq Department of the Air Force
Pentagon, Washington, DC
Air Force Logistics Command (AFLC)
Wright-Patterson Air Force Base, Ohio

Air Force Data Systems Design Center (AFDSDC)
Gunter Air Force Station, Alabama

Hq Tactical Air Command (TAC)
Langley Air Force Base, Virginia

Hq U.S. Air Force, Europe (USAFE)
Ramstein Air Base, Germany

Hq Pacific Air Force (PACAF)
Hickam Air Force Base, Hawaii

Sacramento Air Logistics Center (ALC)
Sacramento, California

314th Air Division
Seoul, Korea

8th Tactical Fighter Wing (TFW)
Kunsan Air Base, Korea

18th Tactical Fighter Wing (TFW)
Kadena Air Base, Japan

36th Tactical Fighter Wing (TFW)
Bitburg Air Base, Germany

50th Tactical Fighter Wing (TFW)
Hahn Air Base, Germany

51th Composite Wing
Osan Air Force, Korea

354th Tactical Fighter Wing (TFW)
Myrtle Beach, South Carolina

4440th Tactical Fighter Training Group (TFTG) (Red Flag)
Nellis Air Force Base, Nevada

6100 Supply Squadron
Kadena Air Base, Japan

Hq Strategic Air Command (SAC)
Offutt Air Force Base, Nebraska

Oklahoma City Air Logistics Center (ALC)
Oklahoma City, Oklahoma

40th Air Division
Wurtsmith Air Force Base, Michigan

379th Bomb Wing (BMW)
Wurtsmith Air Force Base, Michigan